DOCUMENT RESUME

ED 127 183 SE 021 220

AUTHOR	David, Edith, Ed.
TITLE	Investigating Systems: MINNEMAST Coordinated Mathematics - Science Series, Unit 15.
INSTITUTION	Minnesota Univ., Minneapolis. Minnesota School Mathematics and Science Center.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	71
NOTE	125p.; For related documents, see SE021201-234; Photographs may not reproduce well
AVAILABLE FROM	MINNEMAST, Minnemath Center, 720 Washington Ave., S.E., Minneapolis, MN 55414
EDRS PRICE	MF-$0.83 HC-$6.01 Plus Postage.
DESCRIPTORS	*Curriculum Guides; Elementary Education; *Elementary School Mathematics; *Elementary School Science; Experimental Curriculum; *Interdisciplinary Approach; Learning Activities; Mathematics Education; Primary Grades; Process Education; Science Education; *Systems Approach; Units of Study (Subject Fields)
IDENTIFIERS	*MINNEMAST; *Minnesota Mathematics and Science Teaching Project

ABSTRACT

This volume is the fifteenth in a series of 29 coordinated MINNEMAST units in mathematics and science for kindergarten and the primary grades. Intended for use by second-grade teachers, this unit guide provides a summary and overview of the unit, a list of materials needed, and descriptions of six groups of lessons. The purposes and procedures for each activity are discussed. Examples of questions and discussion topics are given, and in several cases ditto masters, stories for reading aloud, and other instructional materials are included in the book. In this volume, six types of scientific systems are explored: (1) simple systems (rolling balls, magnets), (2) a color system, (3) seed dispersal systems, (4) chemical systems, (5) eating systems, and (6) a bulb-lighting system. (SD)

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MINNEMAST

INVESTIGATING SYSTEMS

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	4. USING OUR SENSES
	5. INTRODUCING MEASUREMENT
	6. NUMERATION
	7. INTRODUCING SYMMETRY
FIRST GRADE	8. OBSERVING PROPERTIES
	9. NUMBERS AND COUNTING
	10. DESCRIBING LOCATIONS
	11. INTRODUCING ADDITION AND SUBTRACTION
	12. MEASUREMENT WITH REFERENCE UNITS
	13. INTERPRETATIONS OF ADDITION AND SUBTRACTION
	14. EXPLORING SYMMETRICAL PATTERNS
SECOND GRADE	● 15. INVESTIGATING SYSTEMS
	16. NUMBERS AND MEASURING
	17. INTRODUCING MULTIPLICATION AND DIVISION
	18. SCALING AND REPRESENTATION
	19. COMPARING CHANGES
	20. USING LARGER NUMBERS
	21. ANGLES AND SPACE
THIRD GRADE	22. PARTS AND PIECES
	23. CONDITIONS AFFECTING LIFE
	24. CHANGE AND CALCULATIONS
	25. MULTIPLICATION AND MOTION
	26. WHAT ARE THINGS MADE OF?
	27. NUMBERS AND THEIR PROPERTIES
	28. MAPPING THE GLOBE
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INVESTIGATING SYSTEMS

UNIT 15

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT
720 Washington Avenue S.E., Minneapolis, Minnesota 55455

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The Minnesota Mathematics and Science Teaching Project developed these materials under a grant from the National Science Foundation.

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Fourth Printing
1971

INVESTIGATING SYSTEMS

This unit was developed by MINNEMAST on the basis of experiences of the many teachers who taught an earlier version in their classrooms.

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Complete List of Materials for Unit 15

(Numbers based on class size of 30.)

total number required to teach unit	item	lessons in which item is used
30	** Student Manuals	
1 each	** extra copies of pages 54-57 of Teachers Manual	
1 each	** extra copies of pages 13, 25-29 of Student Manual	
25-30	sheets of construction paper	1
1	roll of transparent tape	1
32	magnets	1
64	* paper clips, 62 jumbo, 2 small	1
30	scissors (or a 6" iron rod for Lesson 1)	1,8
1	* wooden or plastic ruler without metal edge	1
1	strip of cardboard, 1" x 12"	1
2	* spoons, 1 plastic, 1 metal	1
1	sheet of glass or plastic (optional)	1
2	* lumps of clay (optional)	1,14
94	* hexagonal pencils, 1 without an eraser	2
62	* grooved plastic rulers of different colors	2
31	* marbles	2
31	* Ping-Pong balls	2
31	* paper cups	2
80	sheets of newsprint	3,4
30	sheets of finger-paint paper or white construction paper	3
30	cups or wells of red, yellow and blue tempera	3
30	* trays with wells	3,11,12
30	paint brushes and water cups	3
30	aprons or old shirts; towels or rags; sponge; newspaper	3
60	* soda straws	3,12
30 each	* red, yellow and blue Cray-Pas or crayons	3,4

30	*magnifiers	6,8,11,12
1 each	pieces of red, yellow and blue chalk	4,5
1 each	*bottles of green and yellow food coloring	5
30	*plastic cups	5
30	boxes of crayons	5
1	squash or other fruit containing fairly large seeds	6
1	*plastic shoe box, filled with dirt, planted with 20 radish seeds	6,9
90 each	soaked lima beans and peanuts in shell	6
1	roll of paper towels	6,8,9,11
5-10	specimen bags for field trip	7
1	handbook: Living Things in Field and Classroom (recommended)	7,10
3-5	containers filled with dirt or water for specimens	7
30 each	seeds with parachutes, wings, hooks and barbs, and apple seeds	8
1	piece of tagboard; transparent tape	9
1	film: Seed Dispersal	9
2	*balloons	11
1	bottle with narrow neck	11
4-oz. ea.	*baking soda, table salt, and *citric acid ("crystal")	11
5	*teaspoons	11,12
8	large trays	11,12
330	*soufflé cups	11,12
5	sheets of black construction paper	11
30	*medicine droppers	11,12
90	*craft sticks	11,12
7	glasses	12
1 cup	*detergent or soap powder	12
1	lemon (or lemon juice)	12
	red ink	12
1 oz.	*phenolphthalein ("solution")	12

		Unit 15 (cont.)
1 cup ea.	table salt and sugar	12
1	*box of toothpicks	12
1	string of beads	13
1	tangerine or orange	13
30	*mirrors	13,14,16
60	pieces of apple, banana, or nut meats	13,14
1	table knife (or ruler)	14
1	flat stone or block of wood	14
4-5	skulls, or photos of skulls	16
1	chisel	16
1	*piece of soft wood, e.g. pine	16
1	film: Animals – Ways They Eat	16
7-8	boxes or trays containing the following: *1.5 volt flashlight cell; *2.25 volt flashlight bulb; rubber band; *#20 spike; 6-inch strip of masking tape on waxed paper; *length of string ("twine"); *fine, bare copper wire; *soda straw; *fine plastic tubing; *insulated wire; *plastic clothesline; paper strip; *magnetic tape; *ribbon	Section 6

*kit items as well as

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INTRODUCTION

During kindergarten and first grade, children in the MINNEMAST program developed skills in observing isolated objects. Here we introduce them to a new experience—the study of a set of interrelated objects or substances that, taken together, are looked upon as a system. The children isolate an animal's teeth and tongue as parts of his eating system; they see red, yellow and blue as the basic elements of a color system.

This way of looking at things is a great help in understanding a complex situation. The systems concept helps one to focus one's attention on those elements that are relevant to a particular problem. When one reduces a phenomenon to its simplest terms, the phenomenon becomes easier to understand.

The systems concept is introduced through six sets of lessons, beginning with very simple situations. The structure of each section follows a general pattern:

1. The children observe a phenomenon.
2. They identify the objects involved, and observe their properties.
3. They experiment to determine whether each component is essential to the system. They do this by eliminating objects or substances from the system one at a time and observing whether the phenomenon still occurs.

The children repeat this pattern of observation and experimentation in biological, chemical, and physical situations. Through these activities it is hoped they will begin to develop an intuitive sense of the meaning of the term "system" and, more important, a sense of the usefulness of the concept. The children are not expected to make a formal definition of the term at present. The systems concept will be developed further in later units.

What is a System?

A system actually exists only in the mind. It is no more than a convenient way a person chooses to isolate and look at things in order to make them easier to study and understand. A system may be delimited in many different ways.

One type of system consists of those objects, substances or phenomena we decide to group together because of their similarity. We define such a system in terms of those characteristics its members have in common. As we study the system, we may decide to enlarge it or to reduce it still further, in order to understand it better. An example of this kind of system is found in Section 2 of this unit—the system of colors the children are able to produce by mixing pigments. The system includes any color that turns up in their paintings. This is a large group of similar components—similar in that all are colors. In studying the system, the children discover that it can be reduced to three basic components—red, yellow and blue.

Another type of system is a group of components that interest us particularly because they interact in some way. For example, sunlight and droplets of water in the air interact to produce a rainbow. Several such systems of interacting or reacting components are studied in this unit. In one, a number of substances are combined, and a chemical reaction occurs. The children note what substances were combined. Then they determine, by the process of elimination, which of the substances are actually necessary for the reaction to take place. As long as the phenomenon continues to occur, no essential part of the system has been eliminated. Thus, by elimination of nonessentials, the system is reduced to its basic ingredients. Other systems of this type are based on the attraction between a magnet and a paper clip, and the rolling of a ball down an inclined ruler.

A third type of system is a group of elements that all work together to do a particular job. For example, the children study the eating system. The purpose of this system is to take in food. The children determine the parts of the body that are involved in the process, and they are able to see the relation

between the structure and the function of the parts. Some parts of the body that are components of the eating system may also serve other purposes, but that is of no concern in this particular study, because the system has been defined in terms of eating.

Why Systems?

Why is this way of looking at things so useful? Suppose an astronomer wants to study the universe. Its complexity is staggering to the human mind. But when he looks at one portion at a time, he can begin to understand it. First, he might look at the solar system as a subdivision of the universe. But the motion of all the planets, satellites, comets, etc. is still very complex. So he may select just two objects, the earth and the sun, and the gravitational force between them. The study of this simpler system, isolated from the larger one, helps him understand the more complex system as well.

Another example of a complex system is the human body. For the purpose of study it can be reduced to a number of simpler systems, such as the circulatory system, the nervous system, or the system of locomotion. These, in turn, can be narrowed further, according to need. Today, much attention is focused on what goes on in just one cell of living tissue. The study of each of these more and more narrowly delimited systems contributes to the understanding of the larger system, the human body.

This notion of isolating or selecting from a complex background a certain portion for investigation is fundamental to the systems concept. Learning to do this may seem a tall order for a second-grader. But we do not ask the children to make any abstraction of the systems concept. We merely present it as part of a scientific experience suitable for this level.

The work in this unit also introduces other important scientific procedures. The children begin here to develop methods of investigation. They learn that many questions can be answered by experimentation. They see how an experiment can be designed and used to find the answer to a question. They themselves carry out the experiments and record and interpret the results. They examine properties of interacting objects, and

they note the relation between structure and function of parts of an animal's body.

The excitement of discovery may be experienced by the children even in the contrived situations in this unit, if you observe certain precautions. Wherever it is possible for the children to find answers by themselves, do not tell them the answers. Always ask, "How can we find out?"

NOTES ON TEACHING THIS UNIT

Sections 3 and 4 call for the use of two Encyclopedia Britannica Films—Seed Dispersal, and Animals—Ways They Eat. Both are important because they expand the children's experience far beyond what is possible in classroom or field trip. The films may be in great demand, so make a rough estimate of when you will need them, and order them at once. If they are not available from your regular source for visual aids, contact your nearest university or state educational visual aids center.

Each lesson is designed for one session, but a few are somewhat longer and you may choose to divide them. You should expect to complete the unit in about 4 weeks.

You should plan to begin Unit 16, Numbers and Measuring, about two weeks after you start Unit 15, and to teach them concurrently until Unit 15 is completed. After that there will be enough variety in the material in Unit 16 to make both morning and afternoon sessions of that unit enjoyable.

SECTION I TWO SIMPLE SYSTEMS

PURPOSE

- To observe interrelations among members of a set of objects.
- To associate properties of objects with the role they play in a system.
- To determine by experimentation whether or not an object is a necessary part of a system.
- To devise new systems by rearranging and/or adding to objects in a system.

COMMENTARY

The first systems the children work with are very simple assemblages of objects. In the first lesson they work with magnets, paper clips and paper, and in the second lesson with a ball, pencils, and a grooved ruler. In each case they study the interaction among the objects and note how particular properties of an object account for the part it plays in the system.

The emphasis here is on developing an approach to the investigation of systems that can be applied and expanded in subsequent sections of this unit and in future work with systems. The children observe these very simple phenomena, note what objects are part of the systems that produce the phenomena, and experiment with the objects. Whenever a child predicts an interaction he is asked to confirm it by experimentation—to try it and see what happens.

Lesson 1: A SIMPLE SYSTEM EMPLOYING MAGNETS

The first system the children work with is a very simple one. They observe a group of objects—magnets, paper clips, and a sheet of paper—and analyze the interaction among these objects. They then experiment to determine what other objects can be made part of the system.

Anything they learn about magnetism is incidental to the main purpose of the lesson, which is to introduce the idea of a group of objects functioning together as a system. It is not necessary to use the word "system" at this time.

MATERIALS

-- for the class --

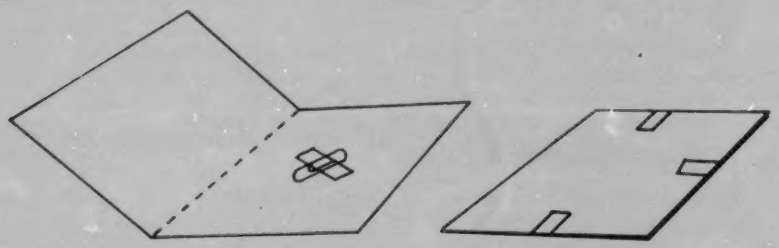
- 6 or 8 pieces of construction paper, each 5 in. x 8 in.
- transparent tape
- 2 alnico magnets, 2 in. long
- 2 small paper clips
- 2 jumbo paper clips, 2 in. long
- pair of scissors or an iron rod, 6 in. long
- wooden or plastic ruler without metal edge
- strip of cardboard, 1 in. x 12 in.
- plastic spoon
- metal spoon

-- for each child --

- 2 alnico magnets
- 2 jumbo paper clips
- 3 sheets of construction paper, each 4 in. x 5 in.

PREPARATION

Take six or eight sheets of paper, 5 x 8 in. and fold each in half. Tape paper clips inside two of the folded sheets, and then tape all the sheets so that the children cannot tell that some of them conceal paper clips.



PROCEDURE

Activity A

1. Arrange the folders at random on the table, and have a magnet ready. In your discussion, do not use the word "magnet" until this first part of the demonstration is completed.

   WHO WOULD LIKE TO COME UP AND TOUCH ONE OF THESE PAPERS WITH THIS ROD?

   If the volunteer touches a paper that sticks to the rod, appear perplexed. Take the paper from him and ask him to touch another paper. Look perplexed again at the result, whether it sticks or not. Call on another child to try it with a few papers. You may have several children try, as long as they continue to be puzzled.

   HOW CAN WE FIND OUT WHY THIS ROD PICKS UP SOME PAPERS AND DOESN'T PICK UP OTHERS?

   Follow through suggestions for investigation until the children discover the reason. After the reason has been discovered, be sure that all see the clip inside the folded paper. At this point, you may begin to call the rod a magnet.

2. The next part of the demonstration confirms the explanation of the mystery by showing that a magnet and a paper clip can indeed support a sheet of paper between them.

Hold up a magnet with a large clip hanging from it.

WHAT IS THE MAGNET DOING TO THE CLIP? (It is holding it up.)

Have a child hold the magnet in one hand and a clip in the other, and bring the two slowly together.

WHAT ARE THE CLIP AND THE MAGNET DOING TO EACH OTHER? (They are pulling or attracting each other.)

Now have the child hold the clip and magnet apart while you insert a sheet of paper between them. Then have the child let the clip and magnet come together again.

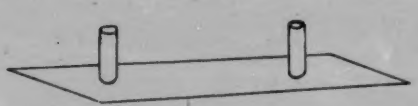
ARE THE MAGNET AND CLIP STILL ATTRACTING EACH OTHER? (Yes.)

WHAT IS KEEPING THE PAPER FROM FALLING? (The attraction between the magnet and the clip.)

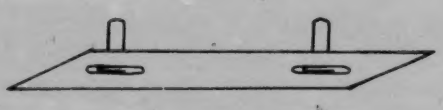
Pick up one of the folded papers with the magnet and hold it up.

WHY DOESN'T THE PAPER FALL? (It is held between the clip and the magnet.)

Now, using two magnets, two paper clips and a sheet of paper, make a tray as shown below. Lift the tray, using the magnets as handles. Show how it can carry a pencil, a rubber band, etc.



View from Above



View from Below

Next, place a large metal clip against one of the magnets, to which it will cling.

IS THIS CLIP A NECESSARY PART OF OUR TRAY?

DOES IT HELP HOLD THE TRAY TOGETHER?

Ask those who say "Yes" to raise their hands, and then those who say "No."

HOW CAN WE FIND OUT? (We can remove the metal clip and see if the tray still works.)

Have a child remove the clip and let the class see that the tray is still a tray. Then ask the same question about the clips under the paper. Have a child remove one. One side of the paper will bend down and you will no longer have a tray. The conclusion, therefore, is that the clips under the paper are necessary parts of the tray.

Now ask whether other objects can be made part of the tray. Children may find it difficult to understand what you mean by making an object part of the tray. Explain that you do not want these objects to change the way the tray is made, but that you want to add some objects to make it better. If suggestions are slow in coming, give the following hint:

TO CARRY THIS TRAY I NEED TO USE BOTH HANDS. COULD I ADD AN OBJECT TO MAKE A HANDLE SO THAT I CAN CARRY IT WITH ONE HAND?

Hold up a ruler.

CAN WE MAKE THIS PART OF OUR TRAY? WHO WILL TRY?

Have volunteers try with the ruler, with a pencil, and then with a pair of scissors. The scissors should make a good handle lying across the tops of the two upright magnets.

WHY CAN THE SCISSORS BE MADE PART OF THE TRAY, BUT NOT THE RULER OR PENCIL? (The scissors stick to the magnet; the ruler and pencil do not.)

WHAT OTHER THINGS WOULD YOU LIKE TO TRY? (Let the children try their suggestions.)

Place all the objects that can be made into a handle—a spoon, a pair of scissors, an iron rod—in one pile. In another pile put those objects that can't be made into a handle—a wooden ruler, a plastic spoon, a pencil, a strip of cardboard. Challenge the children to say which property the objects in one pile have that the objects in the other pile do not have. This is intended to elicit a generalization. It may be made in the form of "These stick to a magnet and those don't." Or a child may say, "These are metal and those are not." (Accept this statement without complicating matters by saying that some metals, such as copper and lead, are not attracted to a magnet.)

Activity B

Provide each child with 2 magnets, 2 jumbo paper clips, 4 rubber bands, and 3 sheets of construction paper, 4" x 5" each. (It saves time to have these on trays for small groups of children.)

SEE IF YOU CAN PUT SOME OF THESE OBJECTS TOGETHER TO MAKE SOMETHING INTERESTING. YOU MAY USE ALL THE OBJECTS OR JUST SOME OF THEM. SEE HOW MANY THINGS YOU CAN MAKE.

During the exploration period, if you see that a child has made what he feels is an exciting discovery, have him report it and demonstrate it to the class.

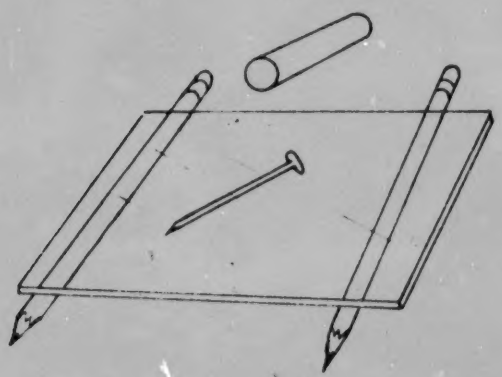
After the children have had time to complete some systems, have them shown to the class, and have the class analyze how each object in the system relates to and affects the other objects.

WHAT DOES EACH OBJECT IN THE SYSTEM DO TO THE OTHERS?

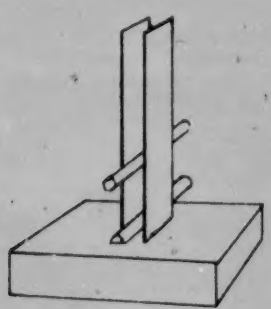
To display some of the children's systems, suspend them from spring clips.

You may want to prepare some of the additional systems shown below for the children to see and manipulate:

A sheet of glass or transparent plastic has a nail underneath. The magnet is moved above the glass and the nail follows it below.



Two rulers and a magnet are stuck into clay. Challenge the youngsters to get the second magnet to stay up in the air.



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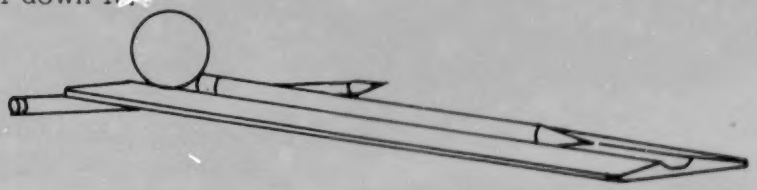
Lesson 2: ROLLING BALLS

The children are shown a ruler propped up so that a ball can roll down it.



First they observe the set of objects and see how the objects are related. Then they turn their attention to the properties of the objects in relation to the roles they play in the system (e.g., the stiffness of the ruler). One pencil keeps the grooved ruler tipped; another keeps the ball from rolling away. The children test the necessity to the system of particular properties.

The teacher poses a problem that challenges the children to modify the system. Finally they use the same objects and additional objects to devise new systems.

This detailed analysis of a very simple system helps lay the groundwork for analysis of more complex systems as the children go along in this unit and in their future work.

At all times be sure to have the children test their predictions. If a child expects a result, always ask him to experiment and see if his prediction is fulfilled.

MATERIALS

-- for the class --

- 4 hexagonal pencils, one without an eraser
- 2 grooved plastic rulers of different colors
- strip of paper, same length and width as rulers
- ping-pong ball
- marble
- paper cup

-- for each child --

- at least two grooved rulers
- 3 hexagonal pencils
- marble
- ping-pong ball
- paper cup

PROCEDURE

Activity A

1. Set up the rolling ball system as shown on page 12. Have the children gather around and identify the familiar objects assembled on the table. Then have them describe the relations of the objects to one another. Positional relations can be determined by observation. The child can see that one end of the ruler is resting on the pencil. But if he should say that the pencil is holding the ruler up, ask "How can we be sure?" and have him test his statement by seeing what happens if he removes the pencil.

2. Lead the children to think of these objects not as a mere collection, but as a system of related objects. If they need help in making observations, you might ask questions such as the following:

   UNDER WHAT NUMBER ON THE RULER IS THE PENCIL THAT IS ON THE TABLE?

   WHAT EFFECT DOES THE PENCIL UNDER THE RULER HAVE ON THE RULER? (It is holding it up.)

   HOW CAN WE BE SURE? (Take the pencil away and see what happens.) Have a child do so.

   WHAT IS THE OTHER PENCIL DOING? (It is keeping the ball from rolling down.)

   HOW CAN YOU SHOW YOU ARE RIGHT? (Test it.) Have a child do so.

WHAT IS THE EFFECT OF THE GROOVED RULER ON THE BALL WHEN THE BALL ROLLS DOWN? (It makes the ball roll down in a straight line.)

HOW CAN YOU TEST IT? (Take the ruler away and see what happens when you let the ball roll off the pencil that was under the ruler.)

2. Now direct the children's attention to the properties of the assembled objects and how they relate to the system.

IF, INSTEAD OF THE RULER, WE USED A STRIP OF PAPER OF THE SAME LENGTH AND WIDTH, WOULD THE BALL ROLL DOWN IN A STRAIGHT LINE?

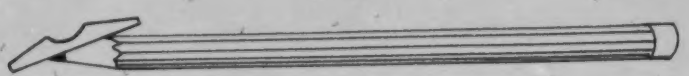
HOW CAN WE FIND OUT? (Try it.)

WHAT PROPERTIES OF THE RULER HELP THE BALL ROLL DOWN IN A STRAIGHT LINE? (It is stiff; it has a straight groove along its length.)

DOES THE RULER HAVE TO BE THIS COLOR FOR THE BALL TO ROLL DOWN IN A STRAIGHT LINE?

HOW CAN WE FIND OUT? (Try a ruler of another color.) Have a child do so.

Rearrange the assemblage so that the pencil tilts the ruler.



WILL THE BALL ROLL THE SAME WAY NOW?

HOW CAN WE FIND OUT?

WHAT PROPERTIES MUST THE OBJECT UNDER THE RULER HAVE IF THE BALL IS TO ROLL DOWN IN A STRAIGHT LINE? (It must be able to hold up the ruler so that one end is higher than the other and so that the ruler is not tilted to one side.)

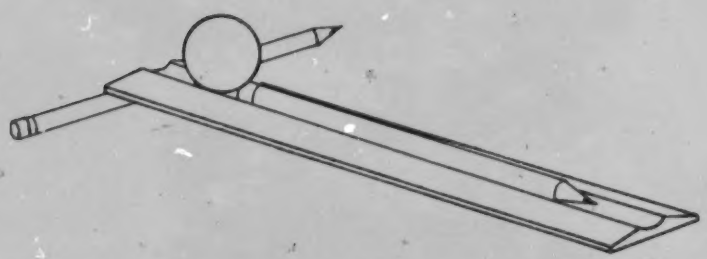
Now look at the pencil on the ruler.

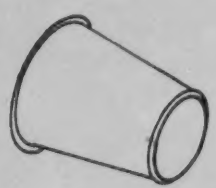
IS THE ERASER ON THE PENCIL NECESSARY TO KEEP THE BALL FROM ROLLING?

HOW CAN WE FIND OUT? (Try using a pencil from which the eraser has been removed.)

3. The children have now observed the relations among the objects in the assemblage, and they have noted the significance of particular properties of the objects. Next they will observe the system in action and consider how to modify the system so that it can serve particular purposes.

Have a paper cup, a marble, and a ping-pong ball ready. Set up the system just as it was at the start of the lesson. Place a paper cup on its side with its opening about 6" away and facing the lower end of the ruler.





Have a child remove the pencil on the ruler so that the ping-pong ball can roll into the cup.

Then ask if the marble would do the same thing. Have a child come up and "work the system" with a marble.

Now place the cup a little to one side so that the rolling ball will miss it. Ask a child to work the system (without moving the ruler) and let the children see that the marble does not roll into the cup.

CAN ANYONE THINK HOW WE COULD ADD AN OBJECT TO THE SYSTEM TO MAKE THE MARBLE ROLL INTO THE CUP?

Tell the children that they will have a chance to try their suggestions out for themselves.

Activity B

Give each child at least two grooved rulers, three pencils, a marble, a ping-pong ball and a paper cup. With these they may devise any systems they choose. Give them the following suggestions one by one, when appropriate. Can they discover how to make a ball roll into a cup that is off to one side of the ruler? Have the children try to use the same objects to make a different rolling ball system from the one they made before. Ask them to find out what happens when one kind of ball hits another kind.

Have the children demonstrate their discoveries. Help them analyze the interactions of the different objects. For example, in connection with the last suggestion above, you may want to ask them what happened to the ping-pong ball after the marble hit it, what happened to the marble after it hit the ping-pong ball, and how the marble would have moved if the ping-pong ball were not in the way.

After the children have finished their own explorations you may set up systems like those below for them to observe and work with in their free time. Systems invented by the children that are different from the one used in the lesson may also be displayed.

Ball rolls back and forth.

Ski-jump

SECTION 2 INVESTIGATING A COLOR SYSTEM

PURPOSE

- To reduce a system of colors to its simplest terms by discovering that all other hues can be made by mixing red, yellow, and blue pigments.

- To represent color mixtures on charts and by symbols.

COMMENTARY

In this section we consider a color system that consists of the colors the children produce when they mix pigments. They will discover that all the colors in the system are produced by mixing the primary colors—red, yellow, and blue. This illustrates the reduction of a larger system to its simplest terms.

The color system is introduced through an art activity in which the children put spots of red, blue, and yellow paints on wet paper and observe the results when they run together. Then they go on to a more detailed study of color mixtures. They determine what color will be produced by each of the different possible combinations of the three primary colors. These combinations and results are recorded in charts and with the use of symbols.

The children then work with a process that is the reverse of mixing colors. They analyze the secondary colors, (purple, green and orange) to find their basic components. They also observe the actual separation of green food coloring into blue and yellow. Finally they use a worksheet that reinforces the idea that the system of colors can be reduced to just the three colors—red, yellow, and blue.

Vocabulary

The children should not be expected to use the term "system" in connection with these activities. However, you should refer to "our system of colors" whenever it seems appropriate so that the children can become familiar with the term.

"Hue" and "color" are synonymous. Try to introduce the word "hue" casually through correct usage. You will note that we use them interchangeably in this manual.

Lesson 3: EXPLORING WITH THREE HUES

This lesson is designed to introduce the children to some characteristics of color. Through their own experiences they discover that a new hue will be produced when paints of two other hues are mixed. They learn what colors they will get from various combinations of red, yellow and blue. They also have some experience with the reverse process of looking at a mixed color and noting which pigments were mixed to produce it.

For this lesson you will want to follow your standard procedure for protecting children and desks from splashing paint.

MATERIALS

-- for each child --

- newsprint
- finger-paint paper or white construction paper, 12 in. x 18 in.
- red, yellow and blue tempera in disposable plastic trays with wells
- water cup
- paint brush
- paper towels
- apron or old shirt
- newspaper
- sponge
- soda straw
- red, yellow and blue Cray-Pas or crayons
- magnifier
- Worksheet 1

PROCEDURE

Give each child a brush, a cup of water, paper towels, a sheet of newsprint, a soda straw, and small amounts of red, blue and yellow paints in a plastic tray.

Demonstrate the correct use of a paint brush, and have the children practice on newsprint. Just the tip of the brush should be dipped into the paint. Excess paint should then be wiped off against the edge of the container. The paint should be applied to the paper with the tip of the brush. Show the children how to sweep the brush gently over the paper. Emphasize that if the children press too hard and scrub the brush against the paper, the hairs will break off and fall out of the brush.

Next, demonstrate the use of the brush for dropping or sprinkling paint on the paper.

Activity A

Tell the children they are going to make some interesting paintings by putting paint of three hues on wet paper and allowing the paints to run together. Explain that their paintings will not have specific forms such as houses, trees, or animals, but that they will be what we call abstract paintings, and different people will be able to imagine them to represent different things.

Give each child a 12 x 18 in. sheet of finger-paint paper or white construction paper. Have each child wet his paper either under the faucet, dripping the excess water off into the sink, or by rubbing over it with a wet sponge. The paper must be very wet, not just moist, if this activity is to be successful.

Have the children drop or brush on separate spots of red, yellow and blue tempera, and then let the paints run together on the wet paper. They can also use soda straws to blow on a spot of paint and splash some of it into a spot of another color.

After the children have had a chance to work with the paints, ask them what they notice happening when two colors run together. Let them discuss their observations as they see new colors appearing on the paper. Ask if they can identify the new colors that appear. Perhaps some children can explain what combinations produced a particular hue. Encourage them to do as much abstract painting as they wish. Ask them to create as many new hues as they can by letting the paints run together.

Choose several of the pictures that show interesting color mixtures. Ask individual children to come to the front of the room, point to specific areas of a picture, and tell which paints might have been combined to produce that particular color. You may also want to have the children analyze and discuss the colors in books or in magazine pictures they can bring from home.

Activity B

Have the children turn to page 2 in their Student Manuals. Have a child read the story aloud. Then ask the children to try to solve Lollipop's problem, using only the colors Lollipop has—red, yellow and blue crayons.

It is expected that the children will not be able to confine the colors within the outlines of the picture and that the colors will mix along the boundary between the petals and the center, and near the stem. If the children do not notice this, direct their attention to those parts of the flower.

DID ANYONE GET SOME GREEN? HOW? (Blue and yellow were mixed.)

DID ANYONE GET SOME ORANGE? HOW? (From yellow and red.)

HAVE WE SOLVED ALL OF LOLLIPOP'S PROBLEM? (No, she wants a purple center on her flower.)

ARE THERE ANY COLORS WE HAVEN'T YET TRIED TO MIX? (Red and blue.)

LET'S TRY MIXING THEM. WHAT NEW COLOR DO WE GET? (Purple.)

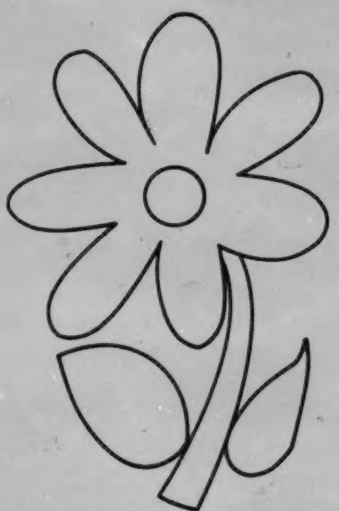
Have the children use the color mixtures they have discovered to make the petals orange, the center purple, and the stem and leaves green.

Once there was a little girl named Lollipop who had just three crayons—a red one, a yellow one and a blue one. Lollipop wanted to color a picture of a flower. So she colored the stem blue, the petals yellow and the center red.

But this was not the kind of flower Lollipop wanted. She wanted a flower with a green stem, orange petals and a purple center. What could she do?

Worksheet 1
Unit 15

Name _____



Take your red, yellow and blue crayons.
Make a blue stem, yellow petals and a red center.

Lesson 4: REPRESENTING THE COLOR SYSTEM

The children will have further experience with the color combinations they investigated in the previous lesson. They will make records in the form of a chart to summarize their observations on mixing pigments. Each of the rows and columns of the chart will be headed by one of the three hues they are working with. At each intersection of a row and a column they will place the colors called for, one on top of the other. Thus the results of the color mixtures will be shown directly. For example, at the intersection of the red row and the red column, red will be placed on red to produce a red circle; at the intersection of the red row and the yellow column, red on yellow will produce an orange circle. You should emphasize the operational similarities between the color chart and the addition charts the children made in Unit 13.

The children will also learn to use symbols such as "r + y $\longrightarrow$ o" to represent the color mixtures.

MATERIALS

-- for the class --

- red, yellow and blue chalk

-- for each child --

- red, yellow and blue Cray-Pas or crayons
- Worksheets 2 and 3

PROCEDURE

Activity A

Refer to the color mixing the children did in the Lollipop activity the day before, and ask what they know about making green. They may answer with a sentence such as "Blue and yellow make green." Ask how we might write the sentence in a shorter way. Someone will no doubt

suggest using the plus sign, and others may suggest such abbreviations as b for blue. In this way lead them to

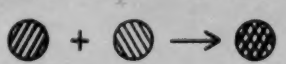
$$b + y \rightarrow g$$

(If other symbols are suggested, they may be used as long as the meaning is clear.) To help make the symbols as clear as possible, you may want to write them with colored chalk, using blue chalk for b, yellow chalk for y, etc.

Ask about how other colors are produced, writing each on the board, until all possible mixtures have been mentioned. Record the suggested mixtures in the following manner—not necessarily in this order, but using this method:

$y + r \rightarrow o$	$r + b \rightarrow p$	$b + y \rightarrow g$
$y + b \rightarrow g$	$r + r \rightarrow r$	$b + r \rightarrow p$
$y + y \rightarrow y$	$r + y \rightarrow o$	$b + b \rightarrow b$

They could also be recorded by using spots of colored chalk.



If the children do not suggest mixing a color with itself, ask what would happen if they did, and suggest that they check their predictions.

After all combinations have been mentioned, ask the children which colors were <u>not</u> needed to make green. Repeat for orange and purple.

Activity B

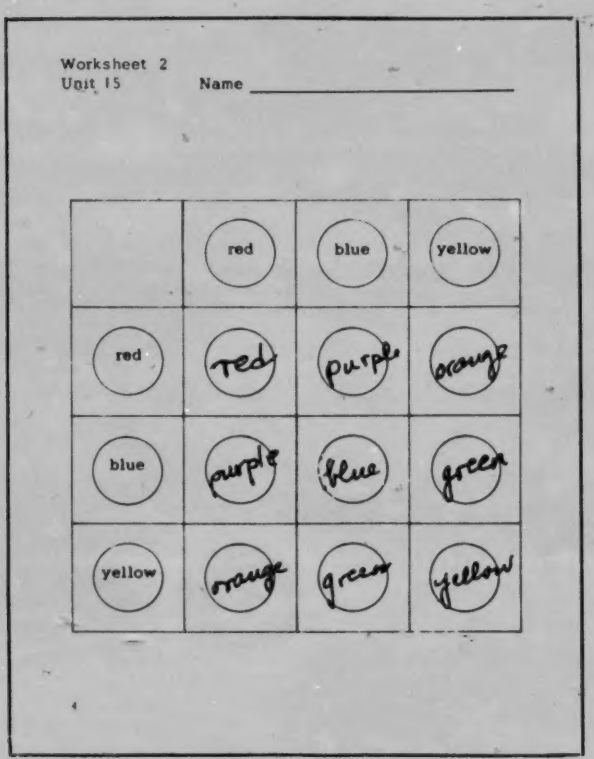
Have the children turn to Worksheet 2, and tell them that they will use this chart to record the information that they have given you, so that they can tell at a glance which colors are needed to make other colors.

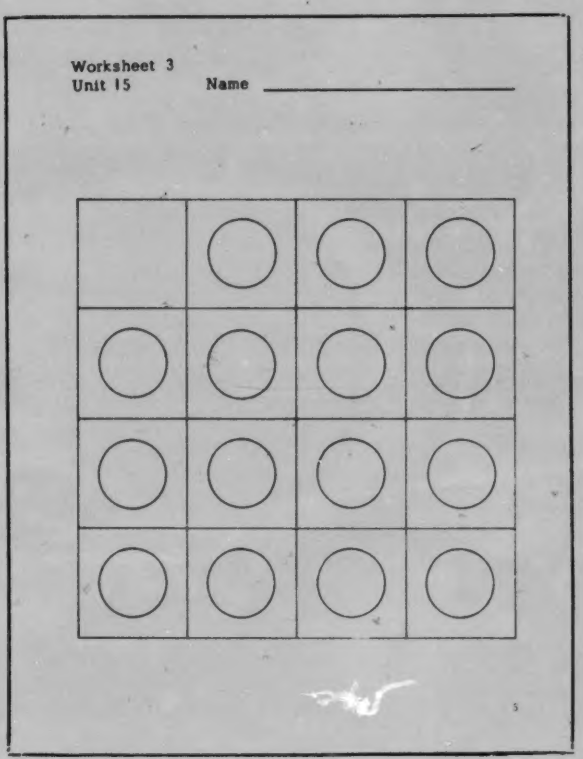
Draw a large chart at the chalkboard to demonstrate what the children are to do. Explain to them that the color at the beginning of each row or column shows what color is to go in all the circles of that row or column. Instruct the children to color

the circle at the head of each row and column with the indicated color. Then explain that they can use this chart similarly to the way they would use an addition chart showing numerals along the edges. Each circle is to have two colors in it, one on top of the other. Note that in every case the children will have to fill in the lighter color first. For example, in both the r-y and the y-r circles they must fill in the yellow first in order to get a good orange.

Choose a few circles at random and have the children guide you in filling them in. They can work on their worksheets at the same time. When the children understand how to proceed, have them complete their worksheets independently.

Worksheet 3 is to be done in the same way as Worksheet 2, except that each child will choose his own arrangement for the primary colors at the head of the rows and columns. In order to get the maximum reinforcement benefit, have the children do this worksheet in their free time later in the day or the next day.





Activity C

Distribute large pieces of newsprint, which are to be folded in half. Each child is to put aside one of his three crayons or Cray-Pas and on one half of the paper make a picture using only two colors, mixing them as he chooses.

Then have each child take the crayon or Cray-Pas that he had put aside, and on the other half of the paper make a picture using all three colors and mixing them to make as many others as possible.

Through this activity the children should realize that three colors (red, yellow and blue) are needed to make all of the other colors. Encourage the children to discuss their discoveries with each other.

Lesson 5: COLOR ANALYSIS

Direct experiences confirm the fact that the system of colors the children have been working with can be reduced to the simplest terms of red, yellow and blue. First they work with a chart in which the mixed colors are specified, and they decide which colors were combined to produce them. Then we take advantage of the fact that sometimes pigments that have been mixed can be separated again. The children work with a commercially prepared green pigment, and discover that it will separate into blue and yellow. The final activity involves a worksheet in which the children cross off those colors not needed to produce a given color.

MATERIALS

-- for the class --

- red, blue and yellow colored chalk
- green and yellow food coloring
- water

-- for each child --

- strips of newsprint or newspaper
- plastic cup
- Cray-Pas or crayons
- Worksheets 4 and 5

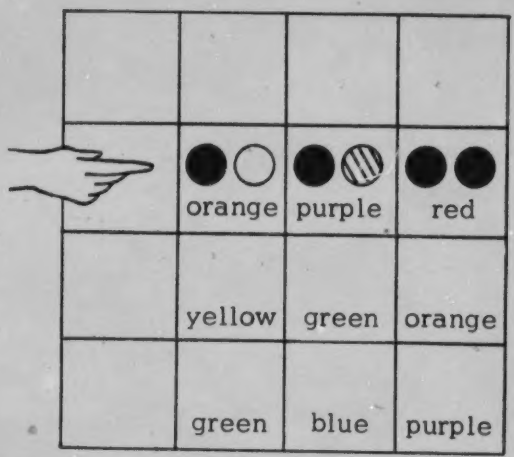
PROCEDURE

Activity A

Have the children turn to Worksheet 4 . Draw a similar chart on the chalkboard. Together, the class should consider how to decide which hue should be placed at the beginning of each row and each column.

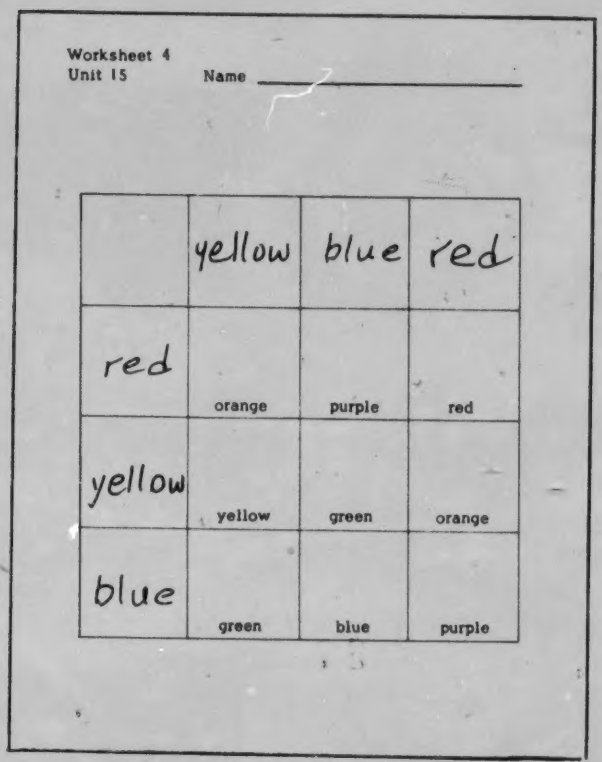
One method is to choose any box and ask which hues are needed to make orange, for example. As the children tell you, make

a yellow dot and a red dot side by side in the box. Go on to the box next to or below it and repeat the procedure. When a row or column has been completed, ask which single hue appears in every one of the boxes.



WHICH HUE DO YOU THINK WE SHOULD PUT AT THE BEGINNING OF THIS ROW? (Red.)

To check that the right hues were chosen, the children can now color each box, first with the lighter and then with the darker hue. When the children are sure of the procedure, have them complete Worksheet 4 independently.



Worksheet 4
Unit 15 Name _____

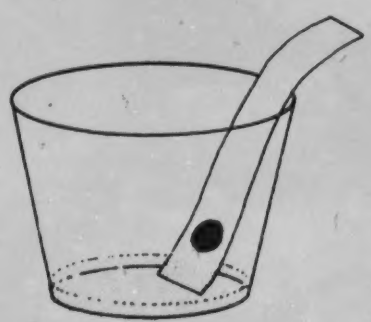
	yellow	blue	red
red	orange	purple	red
yellow	yellow	green	orange
blue	green	blue	purple

27

Activity B

The children have learned through numerous experiences that they can make green by mixing blue and yellow. In this activity they will observe the separation of green into blue and yellow.

Show the children the bottle of green food coloring and ask them what color they see. Do they see any other color besides green? Give each child a strip of newspaper with a drop of green food coloring about one inch from the end. (These may be prepared ahead of time.) Have the children examine the color carefully. Then give each child a small plastic cup with just enough water to cover the bottom. Have the children place the paper so that the end with the dot just touches the water. Warn them against letting the dot itself touch the water.



Now they are to observe what happens. The water will creep slowly up the strip of paper, and when it reaches the spot of green dye, the yellow and blue components of the dye will spread at different rates, so that the two colors can be seen. This will take several minutes, so you may want to plan some other activity that can be interrupted for periodic checks. (It is interesting to watch the changes over a longer period of time, so do not discard the strips after the separation has been observed.)

Next follow the same procedure with yellow food coloring. Do the children expect any color separation this time? Do they observe any separation? Review the representation of color mixtures that was developed in Lesson 4, when you wrote r + y $\longrightarrow$ o on the board. Ask the children how they might

represent what they observed in their experiment with the food coloring. Since they began with green and got yellow and blue, lead them to suggest the following:

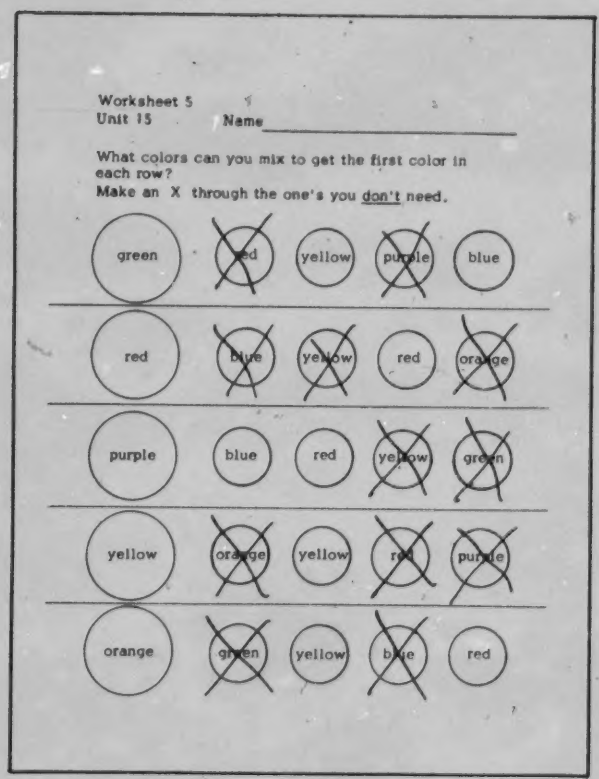
$$g \longrightarrow y + b$$

Ask for suggestions as to how they can represent the results with the yellow dye, and write it on the board.

$$y \longrightarrow y$$

Activity C

Worksheet 5 reviews the fact that only red, yellow and blue are needed for mixing all the colors the children have worked with. This activity emphasizes the fact that we can reduce a larger system of colors to its simplest form.


Worksheet 5
Unit 15 Name_____

What colors can you mix to get the first color in each row?
Make an X through the one's you don't need.

green	red	yellow	purple	blue
red	blue	yellow	red	orange
purple	blue	red	yellow	green
yellow	orange	yellow	red	purple
orange	green	yellow	blue	red

Have the children use their regular desk crayons to color the circles at the beginning of each row on the worksheet. (This time they will use the purple crayon, the green crayon, etc.) If many of your children have difficulty reading color names, you may want them to color all the circles on the worksheet appropriately.

Then they are to cross out those colors in each row that are <u>not</u> needed to make the color at the beginning of that row. Work as a group until they are sure of the procedure.

SECTION 3 SEED DISPERSAL SYSTEMS

PURPOSE

— To investigate seed dispersal systems.

COMMENTARY

A seed dispersal system is an arrangement by which seeds are transferred from the parent plant to some location where, if conditions are favorable, a seed will produce a new plant. The system can be reduced to a few basic elements:

1. The seed.
2. A structure attached to the seed (such as hooks or a parachute) by means of which the seed is carried.
3. Something (such as an animal, wind or water) that moves and carries the seed.

This section begins with a review of what the children already know about the structure and function of seeds and then goes on to the further study of a number of dispersal systems.

Basically, any seed consists of a young plant enclosed in a protective coat. In many kinds of seeds there is also a food supply for the young plant that is to develop.

"Seedcase" is the term we suggest you use in referring to any part of a plant that contains seeds. The technical term for this plant part is "fruit," but this special use of the word may be confusing to the children since it refers not only to apples, pears or cherries, but also to such things as pea pods and cucumbers. (Radishes and carrots are not fruits, since they do not contain seeds.)

In order to study seed dispersal systems, it is essential that some plants with seedcases on them or the seedcases themselves be studied in the field and classroom, because frequently the seedcase is a part of the dispersal system. The system may involve flesh in the seedcase (cherry), hooks on the outside surface of the seedcase (burdock), a silky parachute attached to the seedcase (milkweed), or other devices. (See page 40).

Drawings serve as records of the children's observations. Pages are provided in the student manual on which the children are to make drawings of different kinds of seeds and label them. This is an important part of their work, because when the children have to make drawings they are forced to make careful observations.

PREPARATION

1. Three or four days before you plan to teach Lesson 6, set up a demonstration of the effect of seed distribution on plant growth, as follows:

   Put moist soil in a plastic shoe box. Drop about 20 radish seeds in a pile near one end. Scatter the same number of seeds over the rest of the soil. Cover all with a thin layer of soil, just enough to conceal the seeds. Sprinkle with water and cover loosely with plastic wrap. When you teach Lesson 6 the seeds should be germinating well, and when you are ready for Lesson 9 the difference between the two groups of seedlings should be very noticeable.

   Do not let the children see this set-up until the seeds have germinated and the results can be observed.

2. Before Lesson 7, examine a few possible locations for a field trip. Look for an area in which the children will be able to observe natural plant distribution and seed dispersal, and where it will be permissible to collect seeds, seedcases and plants with fruit attached for use in classroom observation and experiments. A vacant lot is ideal for this. Other possibilities are unmowed edges of alleys, sides of large buildings or cracks in pavement out of which weeds have sprouted, and weedy lawns.

   When you have found a suitable area, take yourself on a field trip and jot down the things that you want to be sure to lead the children to notice. See the MINNEMAST handbook, Living Things in Field and Classroom (page 66) for suggestions about field trips.

3. The night before you plan to do Lesson 6, soak enough lima beans in water so that each child can have several to take apart and examine.

Lesson 6: INVESTIGATING SEEDS

PURPOSE

- To show that seeds have little plants in them.
- To motivate a field trip devoted to consideration of plant distribution.

COMMENTARY

In this lesson the children examine seeds and discover that in each of them there is a tiny plant (an embryo) which will grow if conditions are suitable. The children study pictures illustrating both natural and controlled plant distribution and speculate as to how the plants got there.

MATERIALS

-- for the class --

- squash or other fruit containing fairly large seeds
- box planted with radish seeds, as described on page 31

-- for each child --

- magnifier
- several soaked lima beans
- several peanuts in the shell
- paper towel

PROCEDURE

Activity A

Display the squash. Cut it open to show seeds.

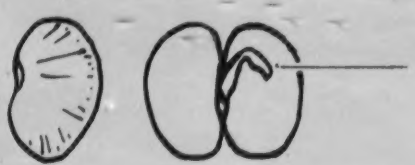
WHAT DO YOU THINK THESE OBJECTS ARE? (Seeds.)

WHAT DO YOU THINK IS INSIDE THESE SEEDS?

HOW CAN WE FIND OUT?

Let each child take several seeds from the fruit. Give each a magnifier. Have the children observe the external properties of the seeds and then open them to see what is inside. Some children may find the tiny plants in their seeds. When all have examined their seeds, have a few describe what they have observed.

Tell the children that they will be able to see the parts more easily in larger seeds, and give a few soaked lima beans to each child. Have the children take the beans apart carefully to see the tiny plant inside each one.



Lima bean

The leaves of the tiny plant are easily identifiable under the magnifier. The two halves of the lima bean that the children find inside the protective covering are the food supply for the young plant. The loose skin is called a seed coat.

On Worksheet 6 the children should draw and label the opened beans showing the tiny plants.

Now distribute a few peanuts in the shell to each child.

CAN WE FIND ANYTHING INSIDE THE PEANUT THAT RESEMBLES WHAT WE SAW IN THE BEAN?

Have the children take their peanuts apart and examine them with the magnifier.

Some will find the young plant easily. Children like to call the young plant "the little man with the beard." The "beard" is made up of the young leaves. The papery covering of the seed is the seed coat.

WHAT PART OF THE PEANUT IS THE SEED? (The part inside the seedcase. The seedcase is commonly called the shell.)

The children should draw and label the parts of the peanut on Worksheet 6 below their drawing of the lima bean.

Activity B

Show the class the picture of a sunflower on page 35.

SUPPOSE YOU WANTED TO GROW A SUNFLOWER IN YOUR YARD. WHAT WOULD YOU DO? (Plant a seed.)

WHAT KIND OF A SEED? (A sunflower seed.)

WHERE WOULD YOU GET IT? (Some children will probably answer, "At the store.")

WHERE DID THE SEED COME FROM BEFORE IT GOT TO THE STORE? (The point should be made that a sunflower seed comes from a sunflower plant.)

SUPPOSE A SUNFLOWER WERE GROWING WILD IN A FIELD. WHAT DO YOU THINK WOULD HAPPEN TO ITS SEEDS? (Birds would eat some; some would fall to the ground, and of these some would be eaten by small animals and others would grow.)

35

Display the germinating radish seeds.

WHAT DO YOU NOTICE ABOUT THE SPACING OF THESE PLANTS? (Some are far apart and some are close together.)

HOW DO YOU SUPPOSE THEY CAME TO BE SPACED LIKE THIS? (Some seeds were planted in a clump and some were scattered.)

WHICH PLANTS DO YOU THINK WILL GROW BETTER?

Have the children speculate, giving their reasons; then say that we will watch the young plants and see how they grow.

Next show the picture of a garden. Have the children turn to the picture on page 9 of their Student Manuals.

HOW DO YOU SUPPOSE THESE PLANTS CAME TO BE GROWING WHERE YOU SEE THEM IN THIS PICTURE? HOW CAN WE EXPLAIN THE ORDERLY ARRANGEMENT OF THESE PLANTS? (The seeds were planted in rows.)

Turn to the picture of the lawn (page 10 in Student Manual).

WHAT IS THE MAN DOING? (Digging dandelions.)

WHO PLANTED THESE DANDELIONS? (No one.)

HOW CAN PLANTS GET TO DIFFERENT PLACES? THEY CAN'T WALK OR RUN, CAN THEY? (The seeds get carried there.)

Tell the children that to find out how seeds get carried to different places they will go on a field trip and experiment with different kinds of seeds in the next lessons.

Lesson 7: FIELD TRIP

PURPOSE

- To observe and try to account for the locations of various kinds of plants in relation to their own kind and to other kinds of plants in the area.

- To discover ways in which seeds are dispersed.

- To collect seeds and plants with seedcases for classroom observation and experiments.

COMMENTARY

This field trip should provide firsthand experience in observing to what extent plants of a given kind grow close together and to what extent they may be scattered over a larger area and interspersed with other plants. It should also provide an opportunity for the children to find seeds where they are actually produced—in a plant. Until now they may have seen seeds only in seed packets, in grocery packages, or on their dinner plates.

It is not at all necessary or important to be able to identify the plants you find on the field trip. Those who are interested in finding the names of their specimens can refer to some of the books recommended in Living Things in Field and Classroom (page 81).

The purpose of this field trip can be achieved by a visit to a place where even only a few plants are growing wild. (See page 31.) The children should be warned beforehand to leave the site of the field trip as undisturbed as possible. They should collect only as many specimens as they need for their experiments.

MATERIALS

- plastic bags of assorted sizes for specimens

- fasteners for bags

PROCEDURE

Activity A

In the field, have a child point out one of the plants common in the area. Then have all look for other places where the same kind of plant is growing. Do this for several kinds of plants, until the children see that there are different kinds of plants and that they are interspersed. The presence of dandelions in lawns, or weeds growing up out of cracks along curbs, illustrates the scattering of a variety of plants.

The children may note that similar plants may be grouped closely, but they should also observe that the cluster is still dispersed enough to indicate that all the seeds had not been dropped directly beneath the parent plant.

Activity B

Have groups of children examine plants more closely to find the seedcases and seeds. They may find examples of the following types:

1. Seedcases with silky down or parachutes, such as dandelion, milkweed, thistle, goat's beard, or sycamore.

2. Seedcases with wings attached, such as ash, maple, elm, or pine. (Most of these will have fallen from the trees, but they may be found on the ground, especially along curbs. Some winged pine seeds may also be found inside pine cones.)

3. Seeds or seedcases with hooks or barbs, such as burdock, cocklebur, Spanish needles (sometimes called devil's pitchforks), sandburs, or tick trefoil. (Specimens of these may be found sticking to the children's clothing.)

4. Seeds other than the above, ranging from tiny mustard, mullein or dock seed to such seedcases as acorns, walnuts and pecans.

EXAMPLES OF SEED DISPERSAL MECHANISMS

Seeds Carried by Parachutes

Thistle Dandelion Goat's Beard Milkweed Sycamore

Seeds Carried by Wings

Ash Elm Maple Catalpa Pine

Seedcases with Hooks

Burdock Sandbur Tick Trefoil Cocklebur Spanish Needles

Seeds without Parachutes, Wings, or Hooks

Mustard Mullein Dock Oak Pecan

The children should be encouraged to experiment with the seed dispersal mechanisms they find. They can blow dandelion or milkweed fluff, note how easily a hooked seed attaches itself to clothing, or bend a mullein stem way over and watch how the seeds are tossed out when the plant is allowed to snap back into position.

Have each child collect one seed-bearing plant or plant-part of as many of the basic kinds listed above as he can. (These materials will be used for experiments in Lesson 8.) Place specimens in plastic bags, blow air into the bags to cushion the more fragile specimens and fasten the tops of the bags. Whenever possible, collect the whole plant or a good part of the plant with the seedcase attached to it, rather than just the seed head.

When you return to the classroom, store the collected seeds and seedcases and arrange the seed-bearing plants in containers. Put the living specimens in soil or water for later use.

Encourage the children to bring other kinds of seeds to class for the next day.

Lesson 8: DISCOVERING COMPONENTS OF SEED DISPERSAL SYSTEMS

PURPOSE

- To examine at least one example of each type of seed dispersal mechanism and to observe how it works.
- To check on the necessity of parts of the dispersal mechanism by observing the effect of removal of some parts.

COMMENTARY

The procedure for this lesson will depend somewhat on the assortment of specimens collected on the field trip. You may want to supplement the seeds collected with additional seeds, to be sure that you have adequate samples of each type. The florist can supply ornamental grasses with barbed seeds, or cattail with airborne seeds. The grocer can supply dill, grapes, squash, tomatoes, nuts, etc.

This lesson is rather long and you may prefer to divide it into two parts, working with two kinds of seeds one day and two kinds the next day.

MATERIALS

-- for the class --

- a few pans of water
- 1 apple

-- for each child --

- several seeds of each category
- magnifier
- scissors
- paper towels

PROCEDURE

Activity A Seeds Carried by Parachutes

Give each child a seedcase with its down or parachute attached. The children should use magnifiers to examine their specimens. Have them describe the structures and then make and label a drawing of their specimens on the upper half of Worksheet 7.

Now have the children experiment with the intact specimens. They should toss them in the air and blow them; they should see if they stick to clothing.

Then have the children examine their specimens with magnifiers again and discuss what they see.

WHERE IS THE PART THAT WILL GROW INTO A NEW PLANT? (The children should indicate the seed.)

WHAT DO YOU FIND ON THIS SEEDCASE? (Hairs, down, little stem, etc.)

WHAT USE ARE THESE PARTS? WHAT HELPS THE SEED TRAVEL? (The down parachute, the wind.)

HOW DO YOU KNOW THE WIND HELPS?

Have the children first try dropping the seedcase in quiet air, and then dropping and blowing it.

HOW DO YOU KNOW THE DOWN HELPS?

HOW CAN WE BE SURE? (We can cut off the down parachute and try blowing the seedcase.)

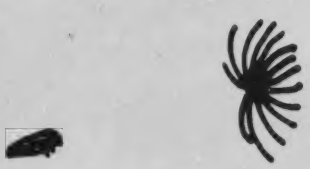
Have the children do this.

CAN YOU THINK OF ANOTHER WAY THIS SEED COULD TRAVEL? (It might float on water.) Try it.

On the chalkboard develop, with the class participating, a diagram of the system by which the seed is dispersed. One way of developing such a diagram is shown below. (Our example is a dandelion seed.)

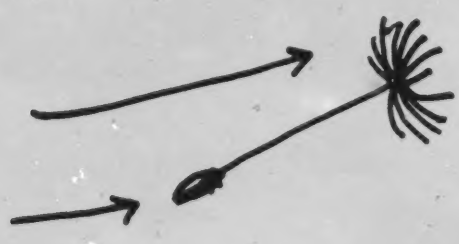
IN WHAT PART IS THE BABY PLANT?
(Draw the seedcase.)

WHAT PART ACTS LIKE A PARACHUTE?
(Draw the down near the seedcase.)

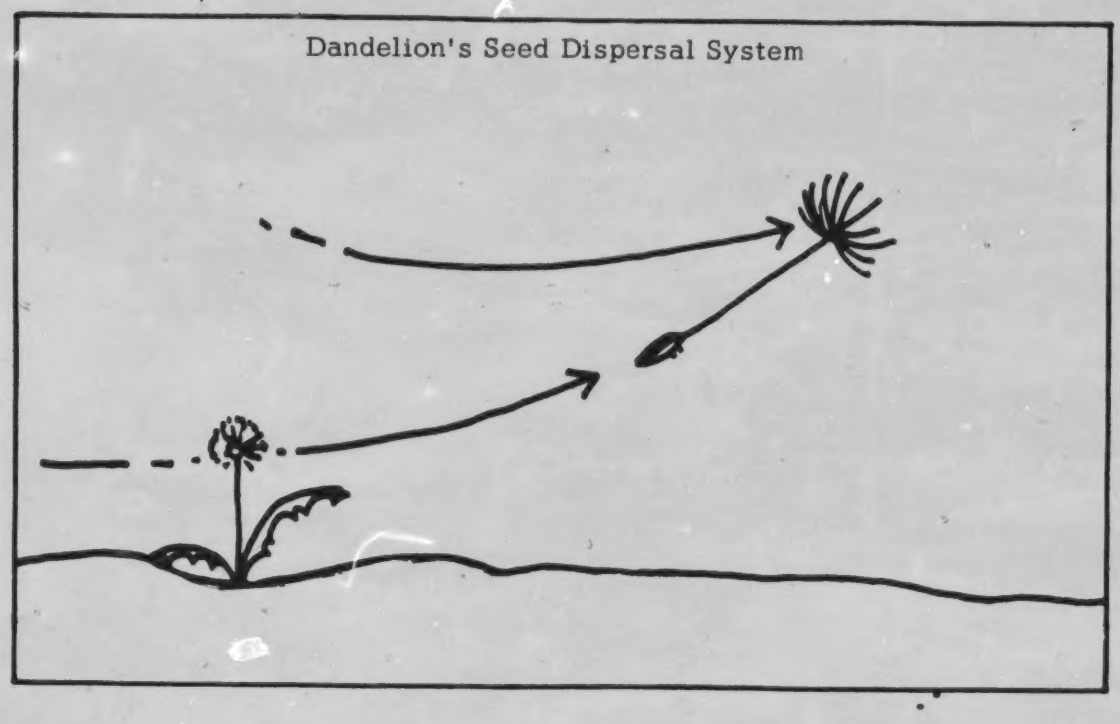


WHAT HOLDS THE DOWN AND THE SEEDCASE TOGETHER? (Add the stem.)

WHAT ELSE HELPS THE SEED TRAVEL?
(Wind. Add arrows.)



HOW CAN WE COMPLETE AND LABEL THIS PICTURE OF THE DANDELION'S SEED DISPERSAL SYSTEM?



Activity B Seeds Carried by Wings

Distribute specimens to the children. Magnifiers may be used to examine the seedcase closely. Have the children find the seed or the place where the seed should be. (Some seedcases may be empty.) The children should then make drawings of their specimens on the lower half of Worksheet 7.

Next have the children experiment with their specimens. Winged seedcases follow interesting spiral paths when dropped from a height of several feet or when tossed into the air. They are easily deflected by air currents, and they float well on water.

WHAT DO YOU FIND ON THIS SEEDCASE? (A wing.)

WHAT DOES IT DO? (It sails through the air and carries the seedcase.)

The children should drop the seedcase and its wing once more to see how it moves.

HOW CAN WE FIND OUT WHETHER IT IS THE WING THAT MAKES IT SAIL THROUGH THE AIR? (We can cut off the wing.)

Now the children should drop the seedcase without its wing, for comparison.

WHAT HAPPENS IF YOU DROP THE SEEDCASE AFTER THE WING HAS BEEN CUT OFF? (It falls straight down.)

With class participation develop a diagram of the system by which the seed is dispersed, somewhat in the manner shown below.

WHAT PART CONTAINS THE BABY PLANT? (Draw the seed.)

TO WHAT IS THE SEED ATTACHED? (Draw the seedcase and wing.)

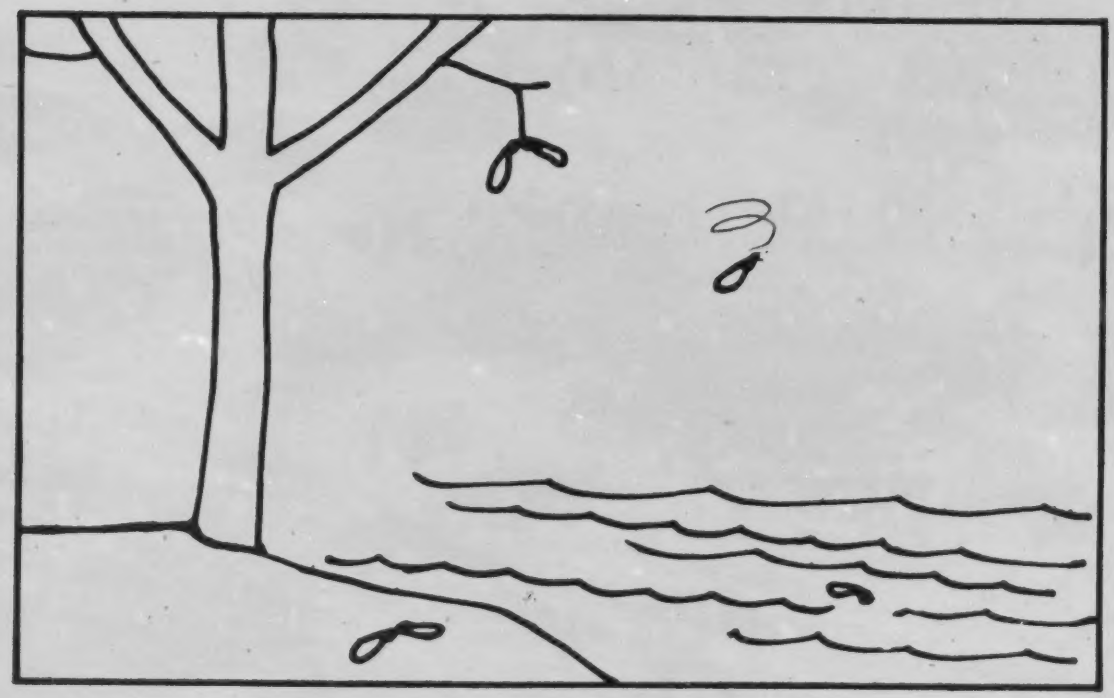
WHAT DO YOU NOTICE ABOUT THIS WING? (It has veins. Draw them.)

DO YOU FIND THESE SEEDCASES AND WINGS SINGLY OR IN PAIRS? (Either way. The two usually separate when they dry and fall from the tree. Draw the other seedcase and wing.)

WHAT HELPS THE SEED TRAVEL?
(Wind. Add arrows.)

IS THERE ANY OTHER WAY IT COULD TRAVEL? (It could float on water. Show seedcase on water.)

The completed system would look like this:



HOW SHALL WE LABEL THIS DIAGRAM? (A Maple's System for Seed Dispersal.)

Activity C Seedcases with Hooks and Barbs

Distribute specimens. The children should examine these seedcases carefully with their magnifiers to see the tiny hooks. They should then make sketches of their specimens on the upper half of Worksheet 8.

WHAT DO YOU FIND ON THE OUTSIDE OF THIS SEED CASE? (Hooks, stickers.)

WHAT DO THE HOOKS AND BARBS REMIND YOU OF? (Fishhooks, spears.)

WHAT DO YOU THINK THEY DO? (They help the seed-case stick to things.)

WHAT KINDS OF THINGS CAN THEY STICK TO?

Give the children time to experiment. Will the seedcases stick to paper? To wood? To cloth? To skin?

WHAT MIGHT THESE SEEDCASES STICK TO OUTDOORS? (Children's clothing; fur of dogs, cats, squirrels, etc.)

HOW WOULD THIS HELP THE SEED TRAVEL? (The animal would carry it.)

COULD THE SEEDCASE TRAVEL WITHOUT ITS HOOKS? (Have the children cut off or blunt the hooks and discover that the seedcase will not stick to things so well.)

COULD IT TRAVEL WITHOUT SOMETHING TO HOOK ON TO? (No.)

Make a sketch of the hooked seedcases on the chalkboard.

WHAT PART OF THIS WILL GROW?
WILL THE OUTSIDE GROW? (No.)

SUPPOSE WE COULD LOOK WITH X-RAY EYES. WHERE WOULD WE SEE THE SEEDS?

Have the children open their burrs to see the seeds. Draw the next picture on the board.

THIS IS HOW IT WOULD LOOK IF WE SLICED IT DOWN THE MIDDLE.

WHAT BESIDES THE HOOKS HELPS THESE SEEDS TRAVEL? (An animal.)

WHAT SHALL WE LABEL THIS PICTURE? (A Burdock's Seed Dispersal System.)

Activity D Seedcases Without Wings, Parachutes or Hooks

Distribute seeds that have no attached parts such as parachutes, hooks or wings. (These include the seeds of most common fruits and vegetables.) Have the children draw a seed on the lower half of Worksheet 8.

Cut an apple in half and show the inside to the children.

HOW CAN THESE SEEDS TRAVEL?

ARE APPLE SEEDS CARRIED BY WINGS? PARACHUTES? HOOKS?

Show the picture of an apple tree. Have the children turn to it on page 13 of their Student Manuals.

WHERE DO YOU THINK THIS APPLE TREE CAME FROM? (It grew from a seed.)

HOW DO YOU THINK THE SEED FROM WHICH THIS APPLE TREE GREW GOT THERE?

Encourage the children to make up stories about how a squirrel might have carried an apple core there years ago, or how a bird might have dropped the seed, or how a child who was walking along eating an apple might have thrown the core there.

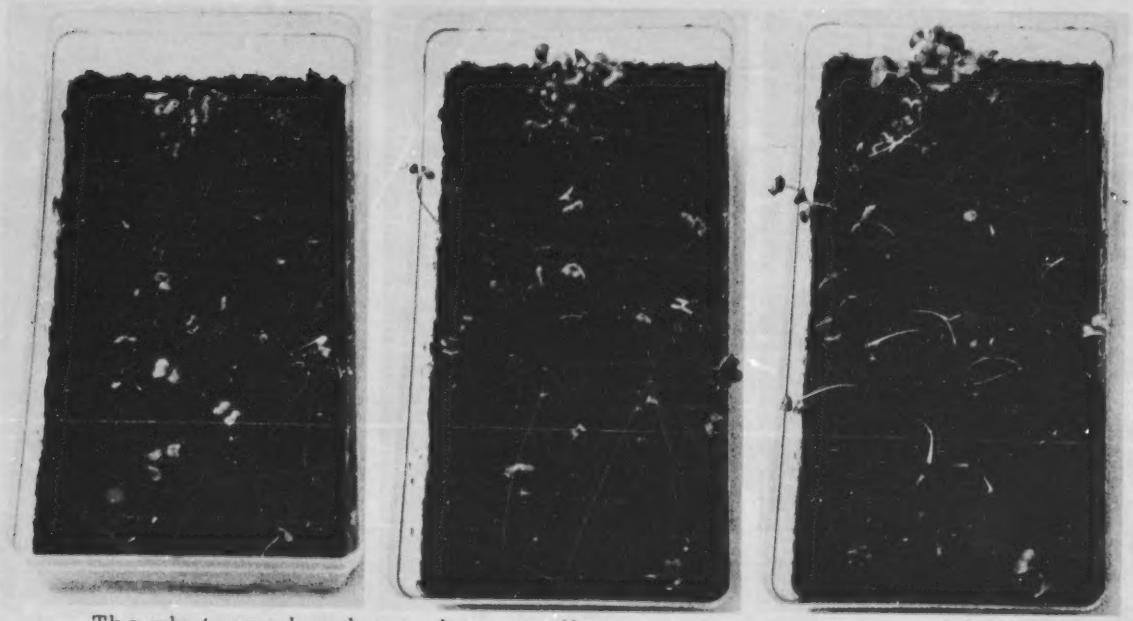
Lesson 9: OBSERVING SEED DISPERSAL IN ACTION

In this lesson the children see that seeds grow better if they have been scattered than if they have been dropped in a clump. Differences between individual seedlings may not be striking, but the scattered seeds should have produced a noticeably greater number of sturdier plants. Sometimes this difference becomes even more striking as the plants grow larger. If you have good growing conditions in your room, especially direct sunlight, you may want to plant another box to check later.

The film, Seed Dispersal, serves to broaden the children's experience far beyond their own field trip and experimentation.

MATERIALS

- box planted with radish seeds
- bowl of water
- paper towels
- tagboard
- transparent tape
- Seed Dispersal, Encyclopedia Britannica Films



The photographs above show seedlings at various stages of growth. The size of yours will depend on the growing conditions.

Activity A

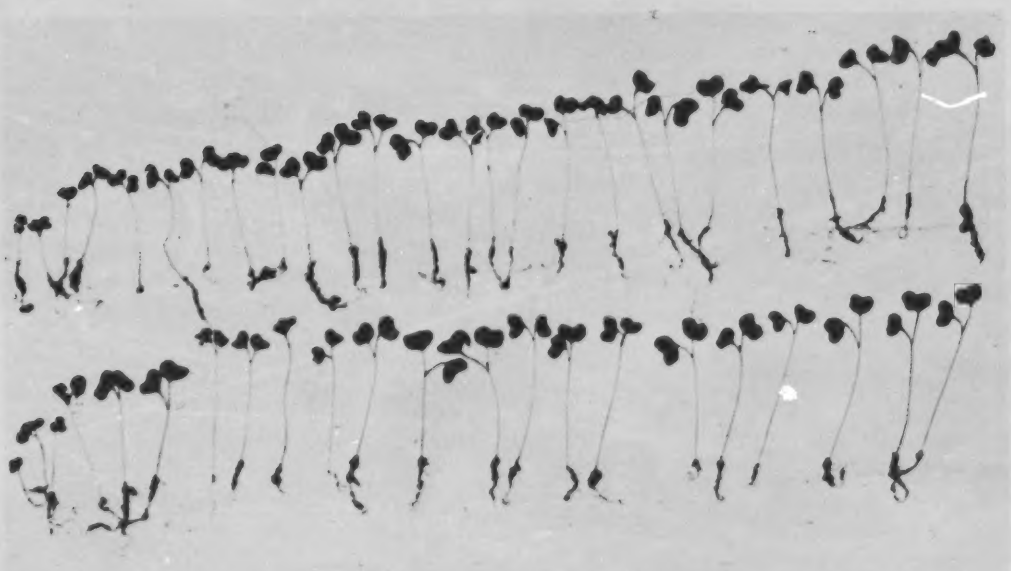
Review what has been learned about seed dispersal mechanisms. Then pose this question:

WHAT DIFFERENCE DOES IT MAKE WHETHER SEEDS ARE DISPERSED OR NOT?

After all suggestions have been made, remind the children that you began an experiment earlier to see how dispersal affects seed growth. Bring out the box planted with radish seeds. Lead the children to note the great difference between the number of seedlings per square inch in the clump and in the rest of the box.

Dig up the seedlings growing in the clump. Separate them carefully, rinse them, and lay them out on a paper towel.

Now, on another towel, lay out each of the young plants growing from the seeds you scattered over the rest of the soil. The two groups of plants can be arranged on tagboard in two rows, each row in order of length. The children should observe the differences between the two groups of plants. They should note length, stem thickness, and leaf size and color.



A discussion of this experiment should lead to the generalization that plants grow better when the seeds have been dispersed, perhaps because the ones growing separately can get more light and water than the ones growing in a clump.

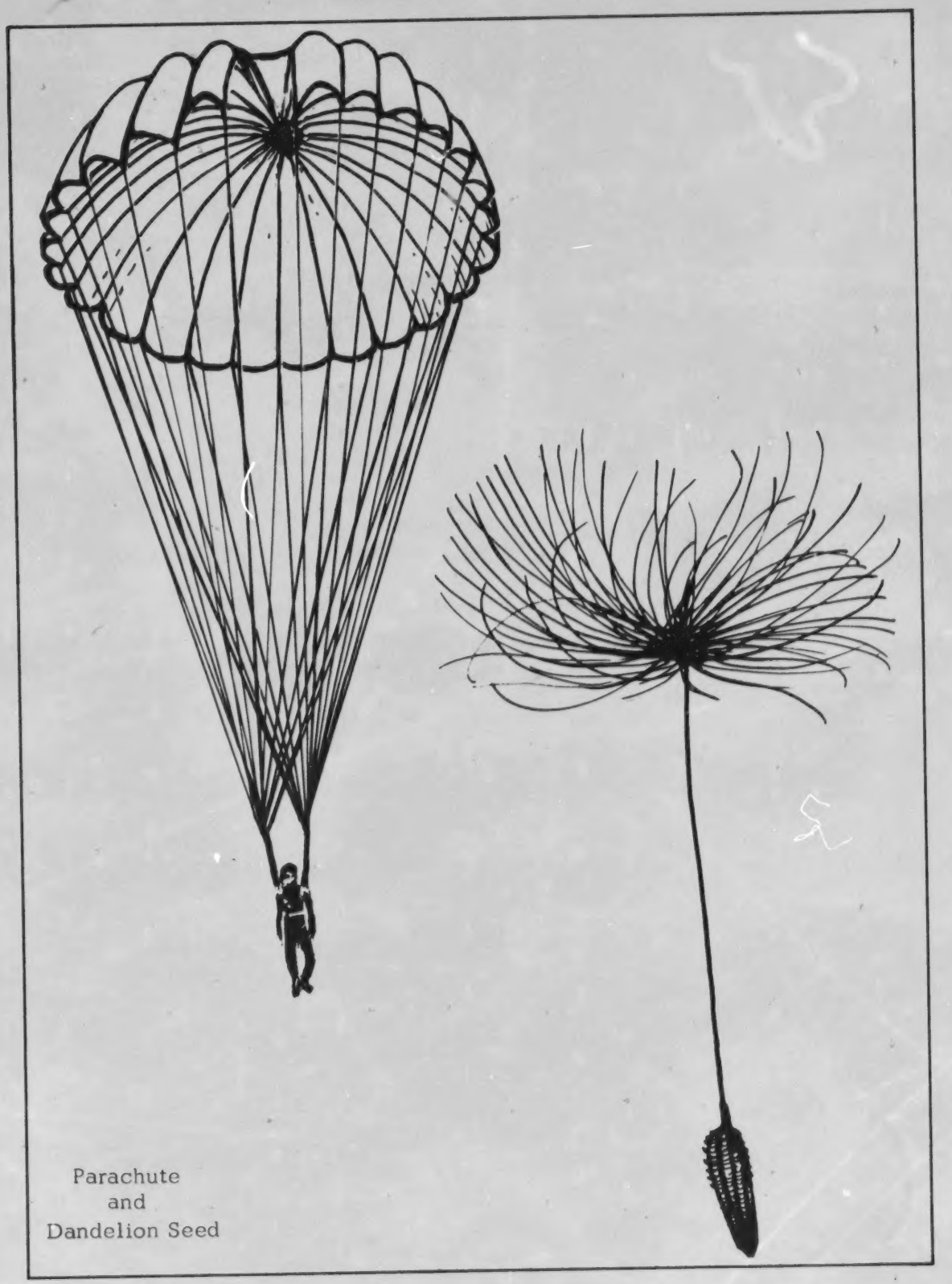
When you have completed this activity, tape the plants to the tagboard, lay paper towels over them and press under some books. After several days remove the books and towels. Appropriately labeled, the specimens on the tagboard can be included in a museum display.

Activity B

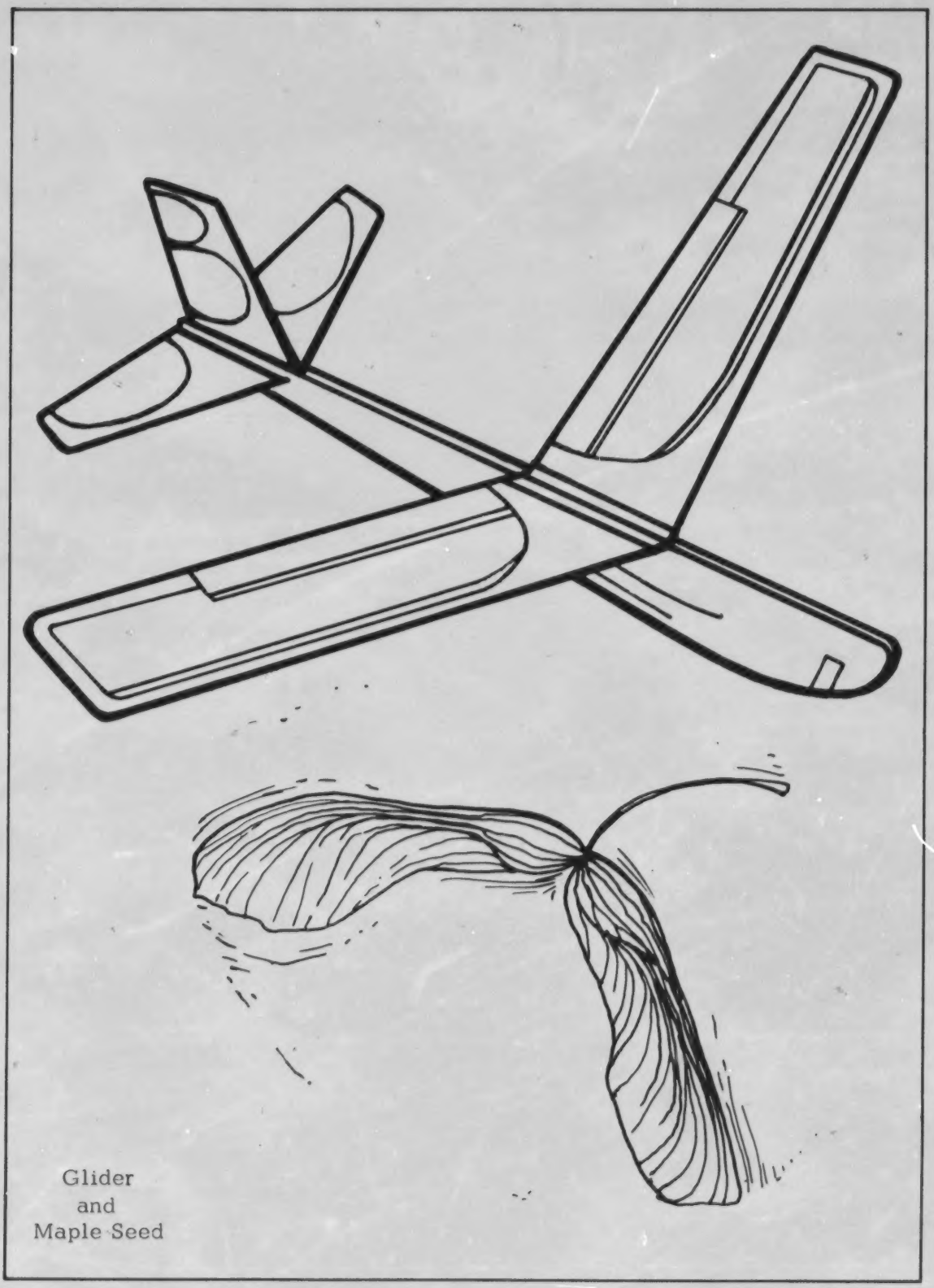
By now the children should understand that it is important for seeds to be scattered. Ask them to invent some imaginary systems for dispersing seeds and to draw pictures of them on page 22 of their Student Manuals.

Some children may enjoy thinking of mechanical parallels to the real systems they have studied, e.g., gliders and maple seeds, or fishhooks and burdock. On a bulletin board display the drawings of such parallels supplied with this unit.

You may also encourage the class to think of other delivery systems useful to move things from one place to another. A bottle with a message in it floating in the ocean can be considered: The bottle is analogous to the seedcase; the message in the bottle is analogous to the seedcase's cargo—the tiny plant; in each case the motive power is external—air or water currents.

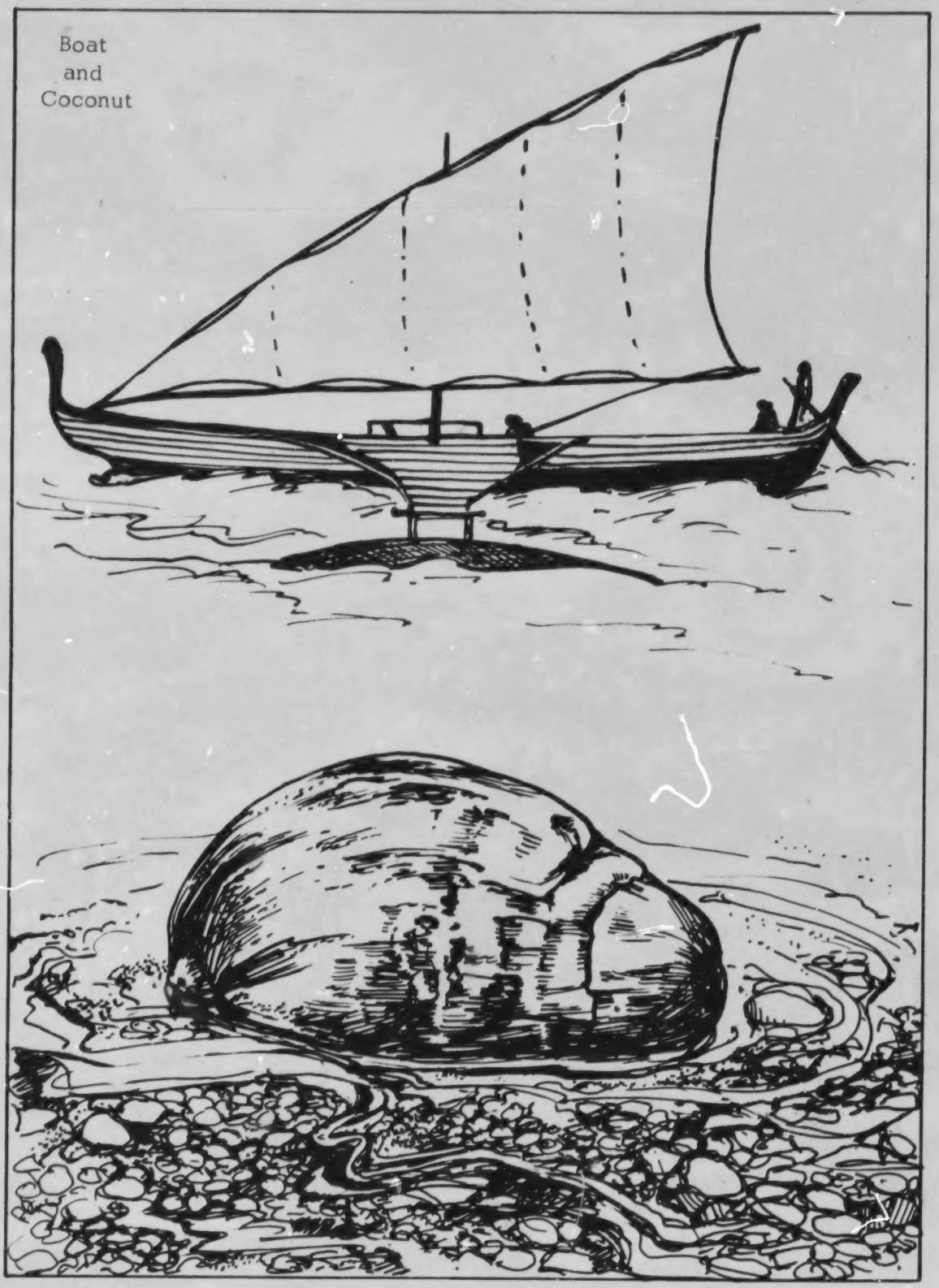


Parachute
and
Dandelion Seed



Glider
and
Maple Seed

Harpoon
and
Spanish Needle


Boat
and
Coconut

Activity C

1. To introduce the film, Seed Dispersal, remind the children that in their work with seeds they did not actually see a seed coming away from a plant, traveling some distance to the ground, and then sprouting up. The film, Seed Dispersal, gives them an opportunity to watch many kinds of seed dispersal mechanisms in action.

   Point out that the people who made this film had to take many, many field trips and work a long time before they could get all the pictures the children will see. Explain that the photographer took a single picture at a time and that these are projected in rapid sequence to give the speeded up effect the children see in the film. This is called time-lapse photography.

2. The children will see from the film that there are more types of seed dispersal systems than the four they studied. For more information the following books should be useful:

Jordan, Helene J.	Seeds by Wind and Water Crowell, 1962
Steffrud, Alfred	The Wonders of Seeds Harcourt Brace, 1956
Selsam, Millicent E.	Seeds and More Seeds Harper, 1959
Webber, Irma	Travellers All Scott, 1944

Lesson 10: SUMMARY

The mystery of Krakatoa should stimulate the children to apply the information they have gathered about seed dispersal. How does a barren island become green again?

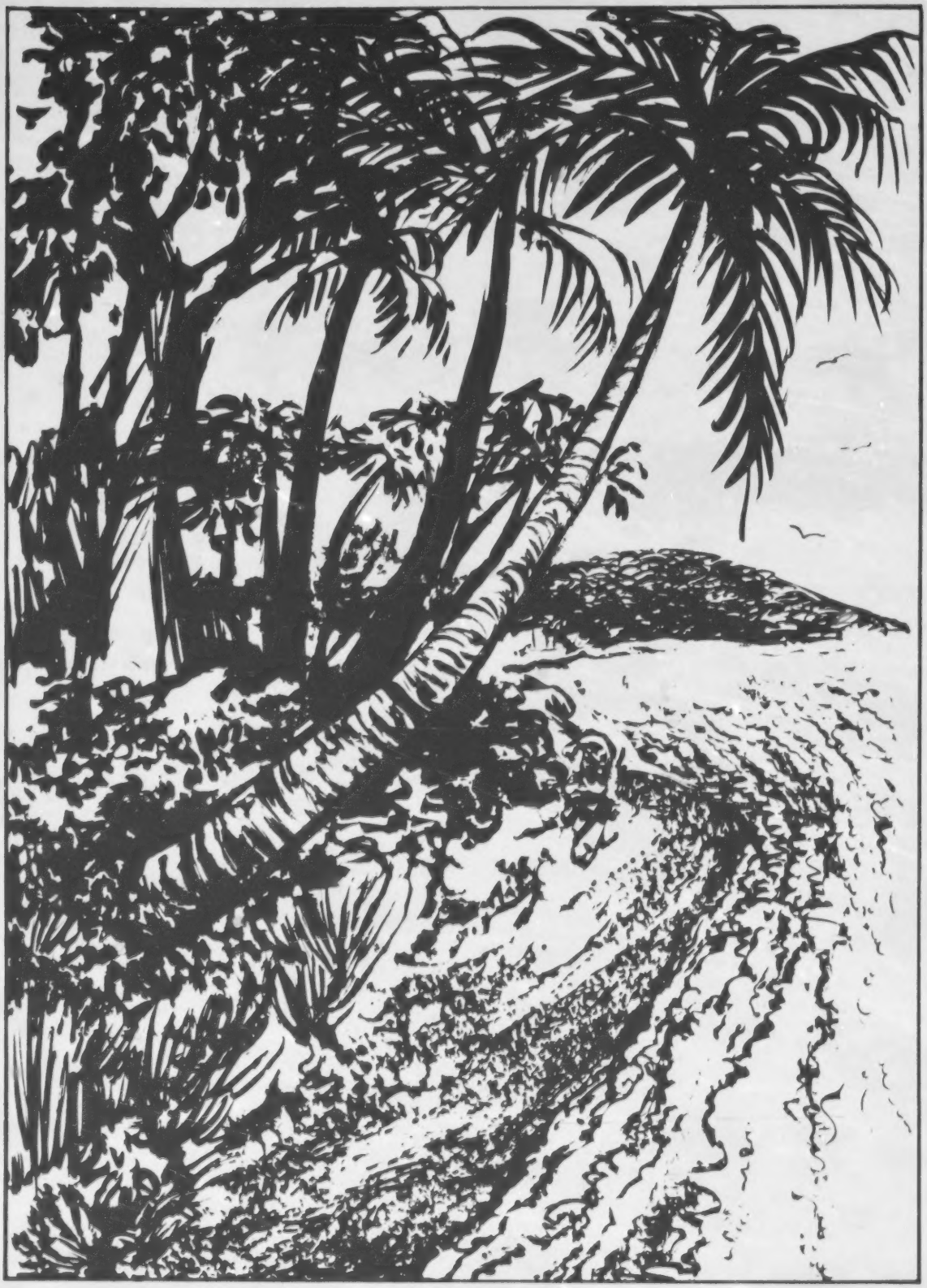
For more information about Krakatoa, see Peter Farb, Ecology, Life Nature Library, Time Inc., 1963, page 64.

The museum exhibit of seed dispersal systems outlined in Activity B can be added to as long as interest is maintained.

Activity A

Read the story of Krakatoa to the class and then have the children help solve the mystery of how the plants began to grow again. If the children need help getting started, remind them that plants grow from seeds, and ask how the seeds might have gotten to the island.

This story is reproduced in the Student Manual (page 14), but the children should not be expected to read it themselves. When the completed manuals are taken home their parents can read the story to them again.



A BIG BLOW-UP

Nearly a hundred years ago there was a small island in the Pacific Ocean called Krakatoa. It looked very much like other Pacific islands. It was green and beautiful. There were forests of trees and fields of wild sugar cane. Palm trees grew along the shore. Beautiful flowers such as morning glories and orchids, and many other plants grew among the rocks and on the beaches.

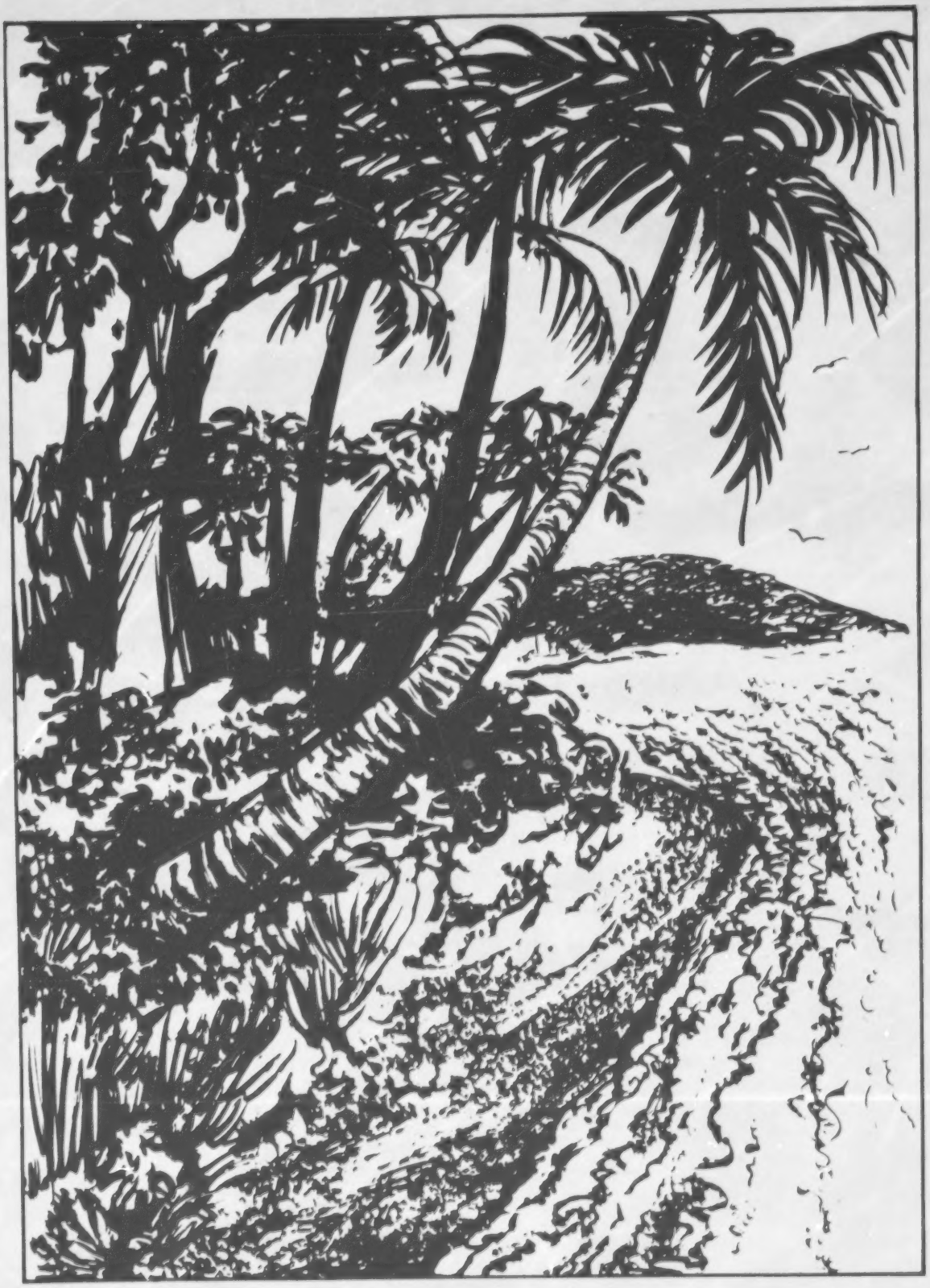
But one morning a volcano erupted on the beautiful island. Red-hot lava poured out over the island. Poisonous gases filled the air, and ashes and dust fell from the sky.

Nothing was left alive on Krakatoa. Everything had been burned or buried. For many days the island was so hot that no one could go near it. Slowly it cooled, but all that remained was lava-rock and ashes. It was as if nothing had ever lived there at all.

But what do you suppose happened? Things did not remain the same for long.

Every once in a while people went back to look at the island. And after a year they saw that there were some plants growing on Krakatoa. This was very interesting! What kind of plants would grow? The people kept close watch to find out.

After three years had passed, plants something like dandelions were growing between the rocks. A young tree had sprouted. Morning glory vines climbed along the shore. There were a patch of wild sugar cane and a few orchids. A few years later coconut trees were growing along the beach and fig trees were growing on the hillsides.



After fifty years the island was almost all green again. It looked very much like it did before the big blow-up.

Can you solve the mystery of how Krakatoa became green again? The nearest land was 25 miles away. Everything on the island was buried by the hot lava from the volcano. Where did the plants come from?

Activity B Setting up a Museum Exhibit

Set up a museum exhibit on seed dispersal. (See Living Things in Field and Classroom, p. 60, for discussion on classroom museums.) The core exhibit in this case should be the four types of seed dispersal mechanisms studied—down or parachutes, wings, barbs, and seeds without visible appendages. Additional seeds that the children bring in can be classified and added to the display.

SECTION 4 TWO CHEMICAL SYSTEMS

PURPOSE

- To set up and observe systems of reacting substances.
- To determine which of the combined substances are necessary for the phenomenon to take place and which are non-essential.
- To learn to answer questions by experimenting and by recording and interpreting data.

COMMENTARY

In each of the two lessons in this section the teacher demonstrates a chemical reaction designed to excite the children's curiosity. In the first lesson a combination of substances produces a gas which is trapped to inflate a balloon, and in the second lesson a red color is made to disappear and reappear. The system in each case is the combination of reacting substances; the resulting phenomenon in each is a property of the chemical reaction.

The focal point of each lesson is the investigation by the children to discover which combination of substances will produce the reaction and which combination will not. They do this by eliminating one substance at a time and observing the results. If the phenomenon occurs, they know that the substance eliminated was not part of the system of reacting substances.

In the course of these lessons, the children have several important scientific experiences.

1. They see that some questions can be answered by experimentation, and they participate in planning the experiments.
2. They carry out the experiments.
3 They record data yielded by the experiments.
4. They make inferences from the results of the experiments.

Lesson 11: A SYSTEM THAT GENERATES A GAS

The children are presented with a problem: How can a balloon be inflated without someone blowing into it? Then a chemical reaction is demonstrated in which a gas is generated. This gas will later be trapped to inflate the balloon. But for the purposes of this lesson the actual inflating of the balloon should be de-emphasized, since it is only a device to introduce the work with the gas-generating system.

The children combine several substances and observe the resulting phenomenon (the mixture bubbles). They go on to experiment—they eliminate one substance at a time, mix the remaining substances, observe the results and record them in a laboratory report. From their data they infer which substances are necessary components of the system of reacting substances. Finally, they see these substances combined and the resulting gas trapped to inflate the balloon.

This lesson is rather lengthy, but most teachers prefer to assemble the necessary materials only once and spend as much time as needed on one day, rather than dividing it into two separate lessons.

MATERIALS

-- for the class --

- 2 balloons, one of them inflated
- bottle over the neck of which a balloon will fit
- 4 oz. baking soda
- 4 oz. table salt
- 4 oz. citric acid
- 3 teaspoons
- water in a container
- paper towels
- large tray for each group of 4 children

-- for each child --

- disposable plastic tray with wells
- 5 soufflé cups
- black construction paper, about 3 in. square
- magnifier
- medicine dropper
- 3 wooden spoons
- Worksheet 9

PREPARATION

To facilitate distribution, assemble materials for each group of four children on a large tray.

PROCEDURE

Activity A

Show the class an inflated balloon.

HOW WAS THIS BALLOON INFLATED? (You blew it up.)

IS THERE ANY OTHER WAY A BALLOON MIGHT BE INFLATED?

Lead the children to the observation that sometimes balloons are inflated from gas tanks.

Tell the class that there are many ways to produce gas and ask if they would like to try one way.

Activity B

Have laboratory equipment distributed. Each child should have a disposable plastic tray with wells, a small square of black paper, a magnifier, a medicine dropper, three small wooden spoons, and 5 soufflé cups.

Have a monitor place about 1/3 teaspoon baking soda in the first compartment of each tray.

Ask the children to examine and observe the properties of the substance they have just been given. They should take a pinch, spread it on the square of black paper and observe it with their magnifiers.

YOU MAY LOOK AT THE SUBSTANCES I GIVE YOU, SMELL THEM, AND FEEL THEM. BUT DO NOT TASTE THEM.

Have the children describe the substance in terms of its properties. Have them guess what the substance might be; then tell them that it is baking soda.

Next have a monitor place 1/3 teaspoon salt in the second compartment of each child's tray. Repeat the above procedure. Tell them that the shiny bits they see with their magnifiers are called crystals. Have the children compare the two substances. Then tell them that the second substance is table salt.

Have 1/3 teaspoon citric acid distributed and repeat the observation, description and comparison; then name the substance.

Give each child water to half-fill the round well in his plastic tray. Have the children compare its properties with the other substances.

Children like to play with the medicine droppers to make bubbles in the water and observe the bubbles inside the dropper. Give them a little time for this experience.

Have the children combine a little of each dry substance in a soufflé cup. (Emphasize that each substance should be picked up with its own little wooden spoon, so as to maintain the purity of the substances.) Next have the children add half a dropper of water to the dry substances. Give them time to observe what happens.

WHAT DO YOU SEE HAPPENING? (Bubbles are forming.)

LOOK AT THE BUBBLES CAREFULLY AND SEE WHAT IS HAPPENING TO THEM. (Some get larger; they move; they burst.)

Some children may have difficulty understanding that a bubble is a quantity of gas surrounded by liquid. They may be helped by a demonstration in which you use a medicine dropper to make bubbles in a glass of water.

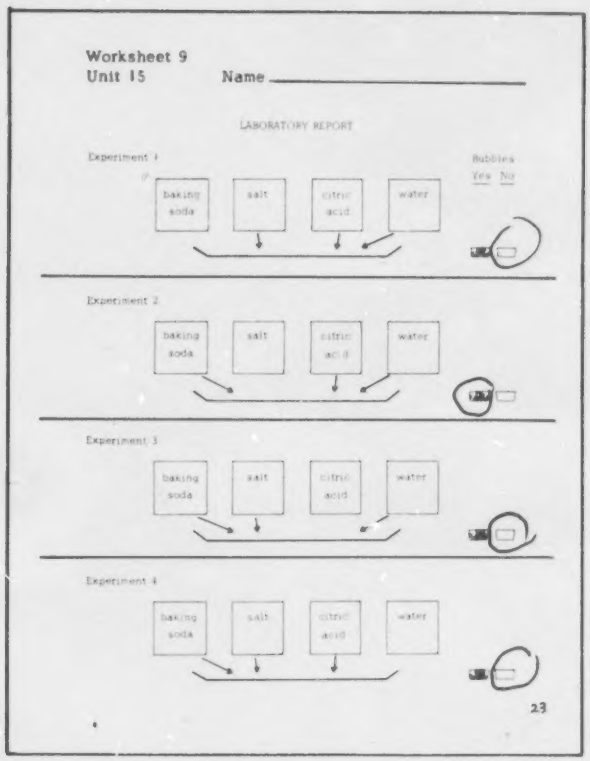
A BUBBLE IS A LITTLE BIT OF GAS SURROUNDED BY WATER. WHEN THE BUBBLE BREAKS, WHERE DOES THE GAS GO? (Into the air.)

Activity C

WHAT SUBSTANCES DID YOU MIX TOGETHER TO PRODUCE THE BUBBLES OF GAS? (Baking soda, salt, citric acid, water.)

DO YOU THINK ALL THESE SUBSTANCES ARE NECESSARY TO PRODUCE BUBBLES OF GAS?

HOW CAN WE FIND OUT WHETHER ALL ARE NEEDED OR WHETHER ONE OR MORE CAN BE LEFT OUT OF THE GAS-PRODUCING SYSTEM?


Worksheet 9
Unit 15 Name _____

LABORATORY REPORT

Experiment 1 — Bubbles: Yes No

Experiment 2

Experiment 3

Experiment 4

baking soda | salt | citric acid | water

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Discuss ways to determine whether all the substances are necessary to produce the gas. Encourage the children to suggest ways before they look at Worksheet 9, which shows one of the possible methods. Should a child suggest a way other than the one described in the worksheet, follow through by asking for two volunteers to try the suggested method. (You may have to help some of these children design laboratory report sheets for recording their results. The systematic recording of results is an important part of this learning experience.)

Most of the children will be following the procedure outlined in the Laboratory Report. Be sure that they understand both the procedure and the method of recording data. Once again warn against contamination, which would affect their results.

Have the class do Experiment I together. Discuss the purpose—to discover whether we can produce bubbles if we leave out the baking soda and combine just the salt, citric acid and water. After they have done Experiment I, have the children report their results orally. Then have one child show at the board how the results can be recorded. Check to see that the children record their results properly.

If some children get different results from the others, have the class consider possible explanations. Perhaps the wrong substances were combined; perhaps the wrong results were recorded. It might even be that the majority were wrong. Suggest that those who have results different from the majority repeat the experiment. The most likely source of error, of course, is contamination.

If the children understand the procedure, let them do Experiments 2, 3 and 4 independently. If they are still unsure, you may want to do Experiment 2 as a group. Be sure that they use a new soufflé cup for each experiment.

After the four experiments are completed, discuss your results. The class should have discovered that the salt is not a necessary component of the system of combined substances that produces bubbles.

Activity D

WHO CAN TELL ME WHAT BUBBLES ARE? (Small amounts of gas in a liquid.)

Set the inflated balloon in front of the class again, and recall the initial problem of how to inflate the balloon without blowing into it.

WE HAVE FOUND A WAY TO PRODUCE GAS BY MIXING CITRIC ACID, BAKING SODA AND WATER. WHAT HAPPENED TO THE GAS WHEN WE PRODUCED OUR REACTION? (It escaped into the air.)

CAN WE FIND A WAY TO CAPTURE THE GAS AND USE IT TO INFLATE A BALLOON?

Encourage numerous suggestions. If no one thinks of it, hold up the bottle.

DOES THIS GIVE YOU ANY IDEAS?

If no one associates the balloon with the bottle, attach the balloon to the neck of the bottle, leading the class to the idea that the substance that will produce a gas can be mixed in the bottle, and that the gas can be captured to inflate the balloon.

Discuss the fact that you must prevent the reaction from taking place before the mouth of the balloon is stretched tightly around the neck of the bottle. Review the fact that three substances are necessary for the reaction. If one substance is placed in the balloon and two in the bottle, they can be kept apart until the balloon is in place. (It is easiest to put the water in the balloon and the dry substances in the bottle.) The balloon will begin to expand as soon as the water in it spills into the bottle and makes contact with the dry ingredients, and the chemical reaction begins. Let the children help you carry out the demonstration.

Lesson 12: A STRANGE RED COLOR

COMMENTARY

In this lesson the children mix five substances together, and the mixture turns red. They then experiment to find which of the five substances are necessary parts of the system of reacting substances that produce the red color.

The following discussion of the reaction is for your own information. Phenolphthalein (fee-nol-THAL-een) is a white powder that will dissolve in alcohol, forming a colorless solution. When added to any acidic substance, such as hydrochloric acid, vinegar or lemon juice, the phenolphthalein remains colorless. When added to any alkaline substance, such as sodium hydroxide, ammonia, soap or most detergents, the phenolphthalein solution turns red. Hence phenolphthalein is known as an alkaline indicator.

Acidic and alkaline substances neutralize each other. When two such substances are combined and the strength of acidity of the one equals the strength of the alkalinity of the other, the neutral mixture will not turn phenolphthalein red.

An alkaline solution with phenolphthalein in it will be red. When you add enough acid to neutralize the alkalinity, the red color will fade. Then if you add enough alkali the red color will reappear. This is the procedure you will demonstrate to the class.

It is wise to run through the demonstration by yourself in advance, because the amounts of the different substances you need will vary, depending on the strength of the acid and the strength of the alkali you use. A single drop of a strong alkali added to a weak acid will produce the red color. You may need to add a great deal of alkali to a strong acid before the red color appears.

MATERIALS

-- for the class --

- 7 glasses
- 5 spoons

- soda straw
- medicine dropper
- 1 cup detergent or soap powder
- 1 lemon
- red ink
- 1/2 cup phenolphthalein solution
- 1 cup table salt
- 1 cup sugar
- water, about 1 quart
- large tray for each group of 4 children

-- for each child --

- disposable tray with wells
- 3 wooden spoons
- medicine dropper
- soda straw
- magnifier
- 6 toothpicks
- 6 soufflé cups
- Worksheet 10

PREPARATION

1. Prepare trays of equipment for the children. Each child will need a disposable tray with wells, three wooden spoons, a medicine dropper, a magnifier, a soda straw, six toothpicks, and six soufflé cups.

2. Half-fill three drinking glasses with water. Into each, dissolve one-half teaspoon detergent. Stir the solution in the first glass constantly while adding just enough phenolphthalein solution to turn it red. (Be careful not to add too much phenolphthalein). To the second glass add enough red ink to make the solution red. Each of these two glasses should have a spoon in it.

PROCEDURE

Activity A

Show the class the two glasses containing red liquids. Have a child squeeze lemon juice into one of the glasses and stir. Then have another child do the same to the other glass. The red will begin to fade from one glass but not from the other. Hold up the glass with the disappearing color.

WHAT IS STRANGE ABOUT THIS RED LIQUID? (When you add lemon juice the color disappears.)

WOULD YOU LIKE TO SEE THE COLOR COME BACK?

Add detergent solution from the third glass, while stirring, until the color reappears. Call attention to the fact that only one of the two red liquids changes color. Tell the class that the other is colored by red ink, and put it aside.

WHO WOULD LIKE TO KNOW HOW TO PRODUCE THIS STRANGE RED COLOR?

Activity B

Have monitors deliver a set of equipment to each child. Set out water and a row of glasses, each containing one of the following: table salt, phenolphthalein solution, detergent powder, sugar. Each glass should have its own spoon or dropper. Tell the children that these are five substances they will put together to try to produce the red color.

Put one-half teaspoon of salt in the first section of each child's tray. Have the children observe its properties. They should look at it with a magnifier, feel it and smell it, but they must not taste it. Have the children remain silent until all have had a chance to determine the properties of the substance.

WHAT DOES THIS SUBSTANCE SMELL LIKE? WHAT COLOR IS IT? HOW DOES IT FEEL? HOW DOES IT LOOK UNDER THE MAGNIFIER? (It is white, it has no odor, it is made of shiny cubes.)

Tell the class that the substance is salt. Next, place a few drops of the phenolphthalein solution in the second section of each child's tray. Have them observe its properties, but be sure to warn them against putting any in their mouths.

WHAT PROPERTIES HAVE YOU DISCOVERED? (It is liquid, and has no color. It looks like water.)

Tell the children the name of the substance.

Next distribute one-half teaspoon detergent to each child. Have the children observe its properties and compare them with the other substances. Repeat with one-half teaspoon sugar. Finally, put a little water in each child's water well. Before the children begin to combine their substances, remind them to use a separate spoon or dropper for each one. They should use a different toothpick to stir each mixture. Show them how to dip a straw into the phenolphthalein and cover the other end with a finger to hold the liquid while transferring it. The straw should be held over the soufflé cup and the end released to let the phenolphthalein drop. Warn against dipping the tip of the straw into the other substances in the cup.

Now the children are ready to produce the strange red color. Tell them what to do step by step:

1. Take a little salt with its own spoon and put it in a soufflé cup. Return the spoon to its proper place with the salt.

2. Take a drop of phenolphthalein with a straw, and drop it into the cup. The top of the straw should be kept covered until the liquid is to be let out.

3. Take a little detergent with its own spoon and add it to the other substances in the soufflé cup. Return the spoon to its proper place.

4. Take a little sugar and add it to the other substances.

5. Use a clean toothpick to mix all the substances together.

6. Add a few drops of water.

Give the children time to observe the results.

WHAT HAS HAPPENED? (A red color has appeared.)

WHAT DID YOU MIX TO PRODUCE THE RED COLOR? (Salt, phenolphthalein, detergent, sugar and water.)

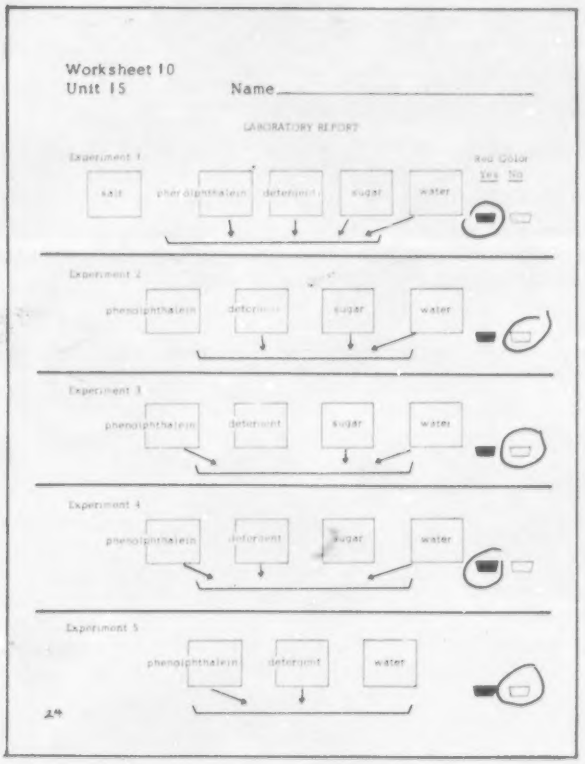
List these on the board, for reference during the next activity.

[You may want to break the lesson here and continue on the following day.]

Activity C

WE MIXED FIVE SUBSTANCES AND PRODUCED A RED COLOR. DO YOU THINK ALL OF THEM WERE NECESSARY?

HOW CAN WE FIND OUT? (We can leave out one substance at a time. If we still get the red color, we will know that the thing we left out was not a necessary part of the system that produces the color.)



Have the children turn to Worksheet 10, the Laboratory Report. Go over it with them to be sure that they understand how to proceed with each experiment and how to note their results by circling the dark dish if a red color appears and the light dish if it doesn't. On the board, copy the section of the Laboratory Report applying to Experiment 1.

Have the class do Experiment 1 as a group. Review the purpose of the experiment.

WHAT WILL WE TRY TO FIND OUT IN EXPERIMENT 1? (We will leave out the salt and see if we get a red color when we mix phenolphthalein solution, detergent, sugar and water.)

Have the children mix the appropriate substances in a clean soufflé cup. Warn them against contamination of their substances. Go about the room to see how they are proceeding. Have the children make oral reports about their results, and ask one child to use the part of the Laboratory Report you copied on the board to show the results. Discuss the results of the first experiment.

WHAT SUBSTANCE DID WE LEAVE OUT? (Salt.)

DID WE GET A RED COLOR? (Yes.)

IS SALT A NECESSARY PART OF THE SYSTEM THAT PRODUCES THE RED COLOR? (No.)

THEN CAN WE LEAVE IT OUT OF THE REST OF THE EXPERIMENTS? (Yes.)

If the children seem sure of the procedure, have them continue with the other experiments independently. If they seem unsure, the class should go through Experiment 2 as a group and then go on to independent work. After all have finished the five experiments, review the results.

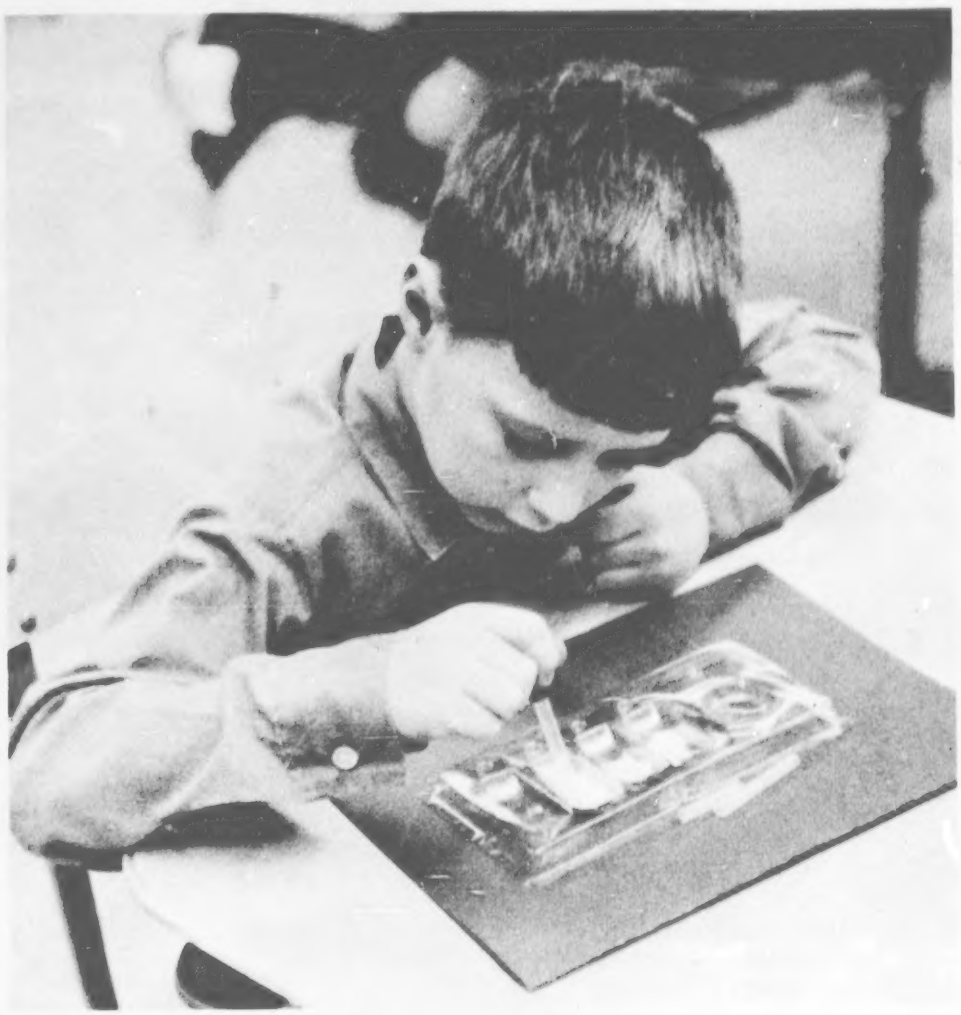
WHICH SUBSTANCES DID YOU DISCOVER ARE NOT NEEDED IN YOUR SYSTEM FOR MAKING A RED COLOR? (Salt and sugar.)

WHICH SUBSTANCES DID YOU DISCOVER ARE NEEDED IN YOUR SYSTEM FOR MAKING A RED COLOR? (Phenolphthalein solution, detergent and water.)

As in the preceding lesson, results may not be uniform. When a child has different results from the others, have the class discuss possible reasons. He may have mixed the wrong substances, or he may have mixed up his spoons, dropped some detergent into the sugar, etc. Have him try to do the experiment again.

Activity D

Some children may want to make the red color disappear, as you did in the demonstration. Provide citric acid crystals left over from Lesson 11 or, if you have none left, give them each a few drops of lemon juice to stir into their red solutions.



SECTION 5 EATING SYSTEMS

PURPOSE

- To determine the parts of an animal that may be considered components of its eating system.

- To study the relation between structure and function of those parts of the body that are components of the eating system.

COMMENTARY

The children begin by studying their own eating systems, determining what parts of their own bodies are part of the system. Then they go on to study eating systems in other animals.

Thus far in the unit the children have been able to determine the components of a system by removing one part or another and seeing whether the system still operates. Obviously they cannot do this when studying systems in living animals. The children must depend on their observations and analytical thinking and the use of models and stories. For example, a story about a cat that temporarily loses the use of its tongue helps them visualize the effect of the removal of the tongue, an indispensable part of the cat's system. The children use models representing parts of an animal's system for eating in order to become aware of how much the structure of an organ and the function it performs are interrelated.

Lesson 13: PARTS OF OUR BODY WE USE IN EATING

The game "Freeze" prepares the children for a demonstration in which a child arrests his motions several times during the process of eating, so that the class can have time to identify the parts of the body he is using.

MATERIALS

-- for the class

- string of beads
- tangerine or orange

-- for each child --

- mirror
- pieces of apple

PROCEDURE

Activity A

Place a string of beads on a table and have a child volunteer to play "Freeze." In slow motion, he is to take up the string of beads, put it over his head, then take it off again and replace it on the table. Then he is to pick it up and put it on again, repeating the sequence of events slowly, over and over again. But as he is doing so, he must be prepared to stop the moment you say "Freeze," and hold the position he is in until you say "Melt." At that point he is to continue what he is doing until you say "Freeze" again.

Have the child slowly pick up the necklace, put it on and take it off again a couple of times. Then at intervals call "Freeze," and ask the class to observe the position of his hands, his head and the necklace each time he freezes.

Activity B

Place a tangerine on the table. (If you substitute an orange, it would be wise to score the skin with a knife, to make the peeling easier.) Have a volunteer come forward to play "Freeze" while eating the tangerine.

Say "Freeze" while the fruit is being picked up.

WHAT PARTS OF HER BODY IS SANDRA USING TO PICK UP THE FRUIT? (Arm, hand, fingers.)

Elicit a detailed response. If a child says merely, "Her hand," ask, "Is she using her fingers?" etc.

Have the child freeze again while peeling the fruit.

WHAT PARTS OF HER BODY IS SANDRA USING TO PEEL THE FRUIT? (Fingers, fingernails.)

LOOK AT YOUR OWN FINGERNAILS. WHAT MAKES THEM GOOD FOR PEELING A TANGERINE? (They are sharp; they can dig into the skin.)

Have the child "freeze" again when she is putting a piece of fruit into her mouth.

WHAT PARTS OF HER BODY IS SANDRA USING NOW? (Hand, arm, mouth, teeth.)

Now your volunteer can "melt" and be dismissed to finish eating the fruit at her seat. Explain to the class that since her mouth is now closed we cannot see what parts inside are working.

Lead the children to the idea that they could use a mirror to watch themselves eating something. Distribute a mirror and a piece of apple to each child. Have the children bite slowly into the apple while looking into the mirror to observe their biting teeth at work. (Those children who have lost some incisors should observe their neighbors.) Then have the children chew the apple slowly to observe their chewing teeth and tongue at work. When the children have finished observing the action of their teeth and tongues, have them describe what they have seen.

Now have them use their mirrors to study the shape of the biting teeth at the front of the mouth and the chewing teeth at the back of the mouth, and to observe how these two kinds of teeth differ in shape. (The biting teeth are thin and sharp, the chewing teeth are broad and flat.)

Lesson 14: RELATION BETWEEN STRUCTURE AND FUNCTION OF TEETH

In this lesson the children study their teeth and see how the different shapes are related to different functions. Experiments are performed using models to represent different kinds of teeth. The children then go on to review the other parts of their own eating system.

MATERIALS

-- for the class --

- table knife or ruler
- flat stone or block of wood
- Plasticene

-- for each child --

- pieces of apple, banana, or a few nut meats
- mirror

Activity A

Give the children mirrors and have them once again observe their teeth. Review the differences in shape between the biting teeth and the chewing teeth.

SUPPOSE YOUR FRONT TEETH WERE BROAD AND FLAT INSTEAD OF HAVING THIN EDGES. WOULD THEY BE BETTER FOR BITING OFF PIECES OF FOOD? HOW CAN WE FIND OUT?

At this point we introduce the idea of experimenting with a model. We use a stone and a knife to represent two types of teeth, to see how the teeth are adapted to do their special job.

IS THERE SOMETHING THAT HAS A THIN EDGE AND SOMETHING ELSE THAT IS BROAD AND FLAT THAT WE CAN USE FOR EXPERIMENTING TO SEE WHICH CUTS BETTER?

You should be prepared with materials that children might suggest as models, such as a table knife and a flat stone, or a ruler and a block of wood.

WHICH OF THESE IS MORE LIKE OUR FRONT TEETH? (The knife.)

IN WHAT WAY IS IT LIKE THE TEETH? (It has a thin, sharp edge.)

TOUCH YOUR FRONT TEETH TO FEEL THE EDGE.

Show the children two pieces of Plasticene of the same size, with which they can experiment to see which shape is better for cutting. Have one child cut the Plasticene with the knife and the other with the stone. The one who finishes first should hold up his two pieces. This will dramatize the difference in efficiency of the two shapes.

WHICH SHAPE IS BETTER FOR A BITING TOOTH? (The thin edge.)

Have the children use their mirrors to look at their biting teeth and see how much the edges resemble the edge of the knife.

YOUR FRONT TEETH BITE. WHAT HAVE YOU SEEN YOUR BACK TEETH DO? (They sq[illegible]sh and grind the food.)

ARE YOUR BACK TEETH MORE LIKE THE KNIFE IN SHAPE OR MORE LIKE THE STONE? (Like the stone.)

HOW CAN WE FIND OUT WHICH SHAPE IS BETTER FOR SQUASHING AND GRINDING—A KNIFE OR A STONE? (Try them and see.)

Have one child use the edge of the knife and another the stone on pieces of apple, banana or nuts and show the results to the class.

The following question is especially important because it draws attention to the relation between the structure and function of an organ.

NOW WHO CAN TELL US HOW THE SHAPE OF TEETH HELPS THEM DO THEIR JOB BETTER? (Biting teeth are thin, which makes them better for cutting. Grinding

teeth are flat, which makes them better for grinding and squashing food.)

Activity B

NOW TELL US WHAT OTHER PARTS OF YOUR BODY BESIDES YOUR TEETH YOU USE WHEN YOU EAT. (Lips, tongue. Children may also recall using their arms, fingers, fingernails, etc.)

Distribute another piece of apple to each of the children so that they can investigate the part the tongue plays in eating. Ask them to wait until you give them the signal to put their pieces of apple into their mouths. Then they are to take a bite and start chewing, but they are not to move their tongues while they chew. After an interval call "Freeze." Tell them that when you say "Melt," they may use their tongues while chewing, to see what difference the use of the tongue makes in eating. When they have finished eating, continue the discussion.

WHAT JOB DOES THE TONGUE DO WHEN WE EAT? (It pushes food onto the chewing teeth and then it pushes food to the back of the mouth so that we can swallow it.)

Have the children use their mirrors again to observe how the tongue moves.

WHAT PROPERTY DOES THE TONGUE HAVE THAT ENABLES IT TO DO ITS WORK? (It bends easily in many directions.)

WHAT DO YOUR LIPS DO TO HELP YOU EAT? (They keep the food from falling out of your mouth while you chew.)

WHAT PARTS OF YOUR BODY DID YOU DISCOVER TO BE IN YOUR SYSTEM FOR EATING? (Arms, hands, fingers, fingernails, biting teeth, chewing teeth, tongue, lips.)

Provide an opportunity for children to include other parts of the body in the eating system. Each child who does so should be asked to explain what function the part has. For example, someone might mention the eyes because they see the food, or the throat which is involved in swallowing.

Lesson 15: THE STORY OF PINTA

In a living organism it is obviously not possible for the children to test the necessity of different components of a system by removing them one at a time and observing whether the system still functions. To help them visualize the role of an individual part, the following story describes the difficulties a cat had when it lost the use of its tongue through an injury.

Pinta

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Pinta was a lovable, fat, little kitten when Frank got her for a birthday present. She had bright green eyes that were big and round. Her fur was jet black, except for her four snow-white feet and two white patches -- one over her left eye and one at the tip of her fuzzy tail. Frank thought she was the prettiest kitten in the world.

Pinta was very playful. She especially loved to play "catch the mouse" with Frank. She might be curled up and purring, or washing her face with one white paw, or licking her soft, round belly to keep it clean, but whenever Frank said, "Catch the mouse, Pinta," she would stop whatever she was doing.

Frank would drag a string with a piece of paper tied to the end across the floor in front of her. Pinta's muscles would bunch up as she got ready to pounce at the paper. She would crouch low on the ground and the white tip of her tail would twitch slowly. Her round green eyes would get narrow and fierce. She would sneak slowly along, following the paper Frank was pulling. Then suddenly she would spring, catch the paper with sharp claws, bite it with her pointed teeth and roll over and over on the floor. After pretending to eat the "mouse," she would wash herself with her long, pink tongue, as she always did after eating real food.

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Pinta would stop playing whenever someone brought her a saucer of milk. Then she would drop the string and run to the saucer. Her little pink tongue would go in and out as she lapped up the milk. Her tongue curled into a little cup at the end and carried the milk into her mouth.

Frank liked to watch Pinta eat. He was amazed at how fast she could lap up a whole saucer of milk. Once, at lunch, Frank decided to see if he could drink milk that way. He poured his glass of milk into a saucer and bent his head down over it the way Pinta bent her furry, black face over her saucer. Frank made his tongue go in and out of the milk in his saucer. He twitched his cheeks, pretending he had Pinta's long, white, wiggly whiskers.

But nothing happened. Except for a little milk that splashed onto the table, the milk stayed where it was in the saucer.

"What's that funny slurping noise?" Frank's mother asked. "Oh, my goodness, Frank, do you think you're a cat?"

"I guess I couldn't be a cat," Frank replied. "My tongue must be different from Pinta's. I can't lap up milk the way she does."

"Well, Pinta can't drink from a glass the way people do," said Mother.

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There was a game that Pinta often played when there was no one to stop her. It was like chasing the string, but it was very dangerous. Near Frank's bed a small lamp was connected to an electrical outlet. The lamp's electric cord hung down in a loop, just like the loop of string in the "catch the mouse" game. Pinta would tap the cord with one white paw to make it swing, and then she would pounce on the swinging electric cord and bite it.

One day an awful thing happened. Pinta pounced on the wire and bit right through the covering. And everyone knows how dangerous an electric cord is when the covering is gone. Pinta let out a terrible yowl!

Frank came running when he heard Pinta. Frank's mother and father came running, too. His father quickly pulled the plug out of the electrical outlet. When the electricity was disconnected they could pick Pinta up. They knew how badly Pinta must have burned her tongue. They called the veterinarian to tell him what had happened. "Pinta has burned her tongue," Frank told the veterinarian. "How will she eat now? She needs her tongue to lap up her milk."

"You will have to try to feed her with a medicine dropper," the veterinarian said.

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So that is what Frank did. He and the medicine dropper were very important parts of Pinta's eating system for the next week.

Pinta did not like being held on her back and fed with the dropper. Poor Pinta! Even though she did not have to move her burnt tongue to lap the milk, it still hurt her to swallow. For a few days, eating was very difficult.

Pinta had another difficulty too. She could not use her tongue to wash herself, and she began to look very shabby. She could not keep her coat glossy and clean without her tongue. She was not at all a happy kitten after her accident.

But one day when Frank was feeding her, she pushed away the medicine dropper and struggled out of his arms. She walked over to the glass of milk from which Frank had been filling the dropper. She poked her small black nose into the glass. Carefully and slowly, her pink tongue came out, reaching down toward the milk. Lap. The tongue disappeared into her mouth. Lap-lap. Then Pinta was lapping the milk as fast as she could. Her tongue was well; she could use her own system for eating again! She was so hungry that she ate for a long time without stopping.

Pinta keeps away from electric wires now. She knows how dangerous they can be, and so does Frank. And Frank knows how important a tongue is for a cat.

In the course of the discussion following the story, raise these questions:

PINTA'S TONGUE WAS PART OF HER EATING SYSTEM. WHAT WERE SOME OTHER PARTS OF THAT SYSTEM? (Lips, teeth. Some child may correctly say that Frank and the medicine dropper were part of the system after her injury. The children might also note that the parts of her body that she used to play "catch the mouse" were also components of her eating system.)

WHAT ELSE DID PINTA USE HER TONGUE FOR, BESIDES EATING? (For washing herself.)

WHAT WOULD HAPPEN TO A SQUIRREL IF HE LOST THE USE OF HIS TEETH? EXPLAIN WHY. (He would die, because the teeth play an indispensable role in his eating. He must be able to crack nuts, gnaw through twigs, etc.)

Lesson 16: INVESTIGATING EATING SYSTEMS OF OTHER ANIMALS

In the first part of this lesson, skulls of several animals will be studied. A set of skulls may be borrowed from your local museum. You will want skulls of an animal that eats only plants (e.g., cow, deer); of one that eats chiefly flesh (e.g., bobcat, fox, dog); and of one that has large gnawing teeth (e.g., beaver, squirrel). In case it proves impossible to obtain the skulls, we provide some photographs. But work with the photographs cannot compare with the actual experience of seeing and feeling the real teeth, so every effort should be made to get the skulls for this lesson.

After the children have studied the differences in skull and teeth structures, they are shown the film, Animals -- Ways They Eat. In this the children can actually see an animal's system at work as far as is possible in a film.

In the last activity in this lesson, the children summarize their experiences with eating systems by studying drawings of several animals and coloring those parts of the bodies that they consider to be components of the animals' eating systems.

MATERIALS

-- for the class --

- skulls as described above, or photos of skulls
- a chisel
- a piece of soft wood, such as pine
- Animals -- Ways They Eat, Encyclopedia Britannica Films. 16 mm, sound, 11 min.

-- for each child --

- mirror
- photographs of skulls (in Student Manual)
- drawings of animals (in Student Manual)

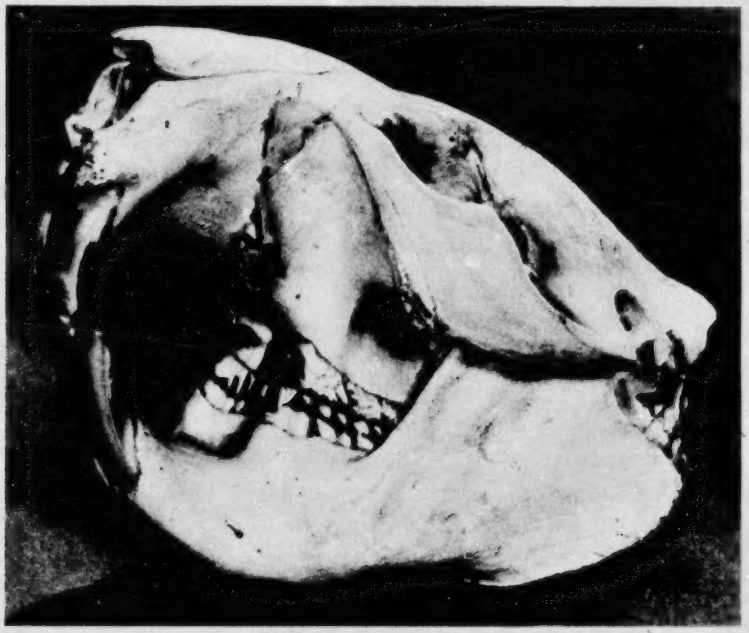
Activity A

SUPPOSE YOU HAD TO BITE THE BARK OFF A TREE OR CHEW THROUGH A LOG. WHAT KIND OF FRONT TEETH WOULD YOU NEED? (Large, strong, sharp teeth.)

WHICH ANIMAL BITES BARK OFF TREES AND OFTEN CHEWS THROUGH THICK BRANCHES? (The beaver.)

DOES THE BEAVER HAVE FRONT TEETH THAT ARE LARGE, STRONG AND SHARP? (Yes.)

In the discussion following this question, lead children to distinguish between something they themselves have actually seen and what they have only read about, heard about, or inferred. Most children will answer "Yes" to the question. Your response to this should be such questions as "How do you know? How close were you to the beaver when you saw his teeth? Suppose someone wanted to see and feel the teeth of a beaver. How could he do it without danger of being bitten?" Explain that when a beaver dies, the teeth remain in its skull. If you could get the skull of a beaver you could have a good look at its teeth without the danger of being bitten. Then present the skull to the class, If you must depend on the photograph, have the children study it on page 25 of their Student Manuals while you display the one supplied to you.



Skull of a Beaver

HERE IS A BEAVER SKULL. WE CAN HAVE A GOOD LOOK AT ITS TEETH.

Take the skull around to the children. Permit them not only to see the teeth at close range, but to feel the sharp edges of the biting teeth. If you are working with photographs, encourage the children to imagine how the teeth would feel.

HOW MANY LARGE BITING TEETH DOES THE ANIMAL HAVE? (Four.)

WHAT PROPERTIES DO THESE TEETH HAVE? (They are larger than the other teeth. They are curved. They have sharp edges. They are thickest near the bone and are thinner toward the biting edge.)

If possible, show a chisel for comparison and demonstrate what a chisel does to wood.

WHAT OTHER KINDS OF TEETH DOES THE ANIMAL HAVE? (Do not try for specific answers. The purpose of this question is to encourage the children to observe differences among the teeth.)

HOW MANY BACK TEETH DOES IT HAVE? (It is difficult to tell from the photograph how many of these teeth the beaver has. There are sixteen—eight uppers, four on each side; and eight lowers, four on each side.)

ARE THESE TEETH SYMMETRICALLY ARRANGED? (Yes. If you are using a skull, have a child do the mirror test if possible.)

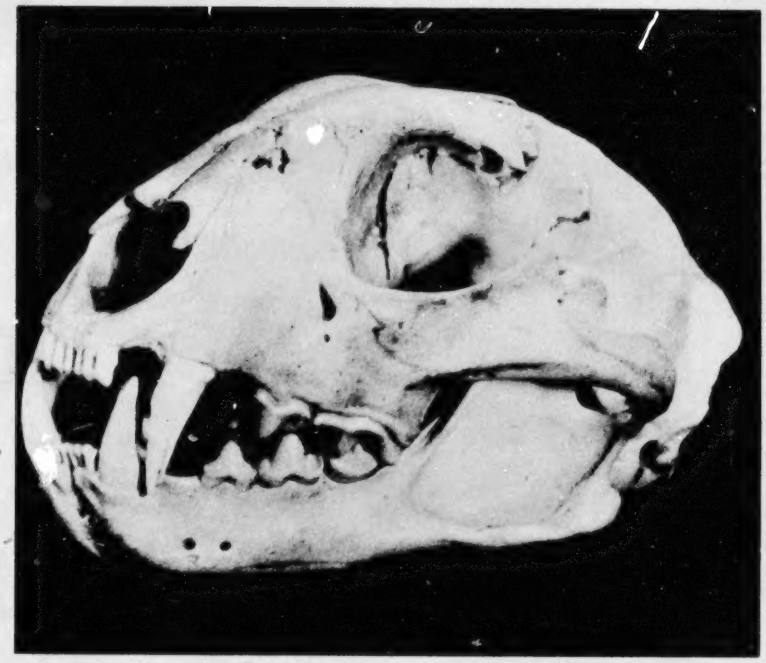
WHAT ARE SOME OF THE PROPERTIES OF THESE TEETH? (The teeth are very hard. Their sides are smooth but their grinding surfaces are rough.)

Let the children run their fingers across the grinding surfaces and discuss how the hard edges are related to the job these teeth do.

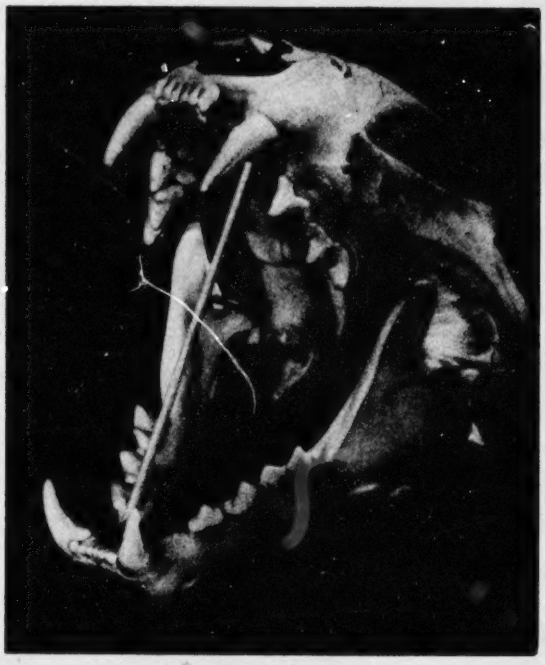
LET US COMPARE THE ANIMAL'S TEETH WITH HUMAN TEETH.

Have the children use mirrors to examine their own teeth for comparison with the skull or with photographs. Ask about resemblances and differences.

Next show the skull or photographs of a meat-eating animal (bobcat, fox, dog), but do not identify the animal immediately. (These appear on pages 26-27 of the Student Manual.)



Skull of a Bobcat



Skull of a Bobcat

LET'S LOOK AT THE TEETH OF A DIFFERENT ANIMAL. Hold up the skull if you have one, and add, I AM GOING TO BRING IT AROUND. YOU CAN NOT ONLY OBSERVE ITS TEETH, BUT YOU CAN PUT YOUR FINGER INTO ITS MOUTH AND FEEL THE TEETH.

WHICH ARE THE LARGEST TEETH? Have the children point to the teeth.

HOW MANY OF THESE LONG TEETH DO YOU SEE? (Usually four.)

WHAT DO YOU THINK THESE TEETH DO?

Here is an opportunity for the children to speculate and infer. If they say, "The teeth are for biting," ask, "If the teeth are for biting off a piece of food, shouldn't they be shaped like the biting teeth of a beaver or like our own biting teeth? Are they?" Have the children look and see that these teeth are not like our biting teeth. "Then what can they be for?" If no one answers, your next hint will elicit the answer.

I AM PLACING MY FINGERS BEHIND THESE LONG CURVED TEETH. (If you are using photos, substitute: IMAGINE PLACING YOUR FINGERS BEHIND THESE FOUR LARGE TEETH.)

IMAGINE MY FINGERS TO BE A LIVE MOUSE OR A LIVE BIRD JUST CAUGHT BY THIS ANIMAL. WHAT JOB DO YOU SEE THE BIG TEETH DOING? (They prevent the mouse or bird from escaping.)

THIS IS A SKULL OF A (name the animal). HOW DO YOU SUPPOSE THIS MEAT-EATER GETS ITS FOOD? (It probably catches animals.)

LOOK AT THESE TWO LARGE TEETH AGAIN. WHAT PROPERTIES HELP THEM HANG ON TO THE ANIMALS THE MEAT-EATER CATCHES? (They are long and curved to hold in a small animal. They are pointed and can stick into an animal that is larger than the mouth. They are big and strong so that even a strong animal cannot escape.)

LET'S LOOK AT THEM AGAIN AND FEEL THEM. WHAT PROPERTIES DO THE BACK TEETH HAVE? (The teeth are hard and pointed. They are white. They are shiny.)

WHY DO YOU SUPPOSE THESE BACK TEETH ARE DIFFERENT IN SHAPE FROM THE BACK TEETH OF A GNAWING ANIMAL OR FROM OUR BACK TEETH? (They have a different job to do.)

WHAT DO YOU THINK THEIR JOB IS? (Their job is to tear raw meat.)

HOW DO THE FRONT TEETH OF A MEAT-EATER RESEMBLE HUMAN TEETH?

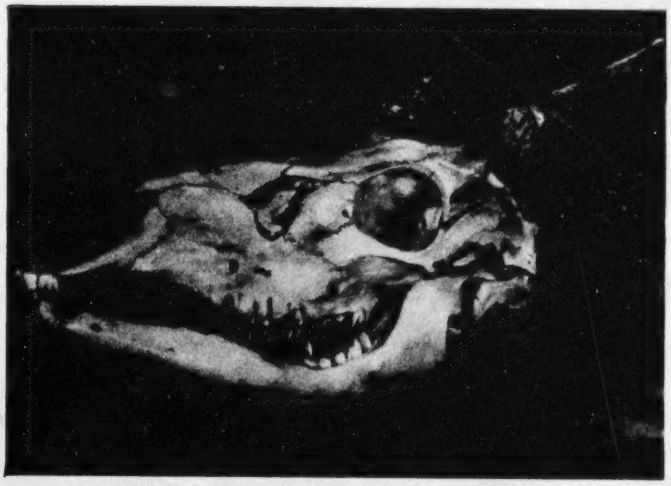
Have the children make a direct comparison, using skulls, photographs and mirrors to note that in each the front teeth are chisel-shaped.

WHAT DO YOU THINK THE JOB OF THE FRONT TEETH IS? (To bite off pieces of food.)

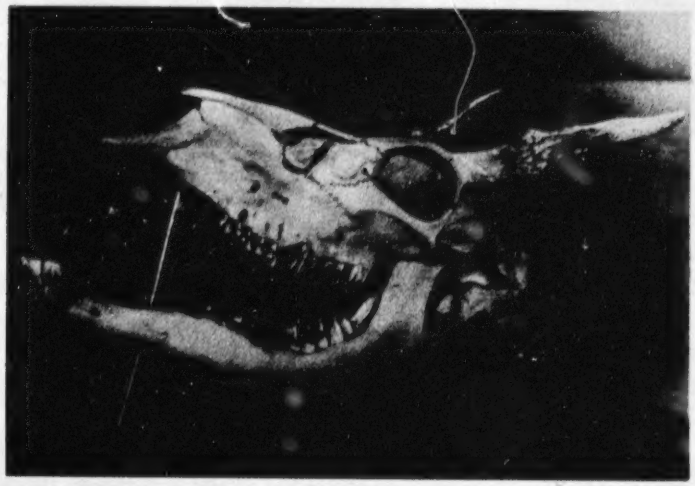
WHAT ARE THE DIFFERENT WAYS WE HAVE SEEN THAT TEETH ARE USED? (Gnawing, grinding, cutting, tearing.)

LOOKING AT THE KINDS OF TEETH THIS ANIMAL HAS, WHAT DO YOU THINK IT DOES TO ITS FOOD? (It tears and cuts it.)

Now display the skull or photographs of the plant-eating animal. (These appear on pages 28-29 of the Student Manual.)



Skull of a White-tailed Deer



Skull of a White-tailed Deer

LET US LOOK AT THE TEETH OF STILL ANOTHER ANIMAL. THIS IS A SKULL OF A (cow, deer, moose). WHERE ARE MOST OF ITS TEETH—IN THE FRONT OF ITS MOUTH OR IN THE BACK? (In the back.)

ARE THE BACK TEETH SHAPED LIKE CUTTING TEETH OR LIKE TEETH THAT GRIND AND CRUSH FOOD? (Like grinding teeth.)

HOW MANY BITING TEETH DOES THE PLANT-EATER HAVE IN THE UPPER PART OF ITS MOUTH? (None.)

IN WHAT DIRECTION DO THE LOWER BITING TEETH POINT? (They point forward.)

SINCE THE PLANT-EATER DOESN'T HAVE ANY UPPER BITING TEETH, HOW DO YOU SUPPOSE IT BITES AND TEARS ITS FOOD?

Encourage speculation, especially on the use of the tongue in conjunction with front lower teeth. Point out to the children that these are only speculations and that to find out the answers they should actually observe the animals as they eat. This is possible with a film.

Activity B

Animals — Ways They Eat shows the many ways that animals of different kinds are adapted to get and eat their foods. Many kinds of animals, living in different habitats and eating various kinds of foods, are shown. A number of close-up scenes show the various body parts that are used by animals to get and to eat their food.

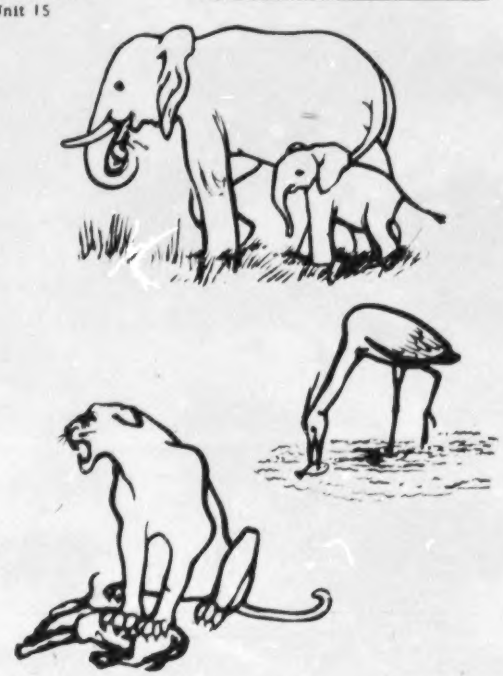
After the children have seen the film, have them describe the eating system of some of the animals.

Activity C

Worksheets 11-14 show pictures of a number of animals. The children are to color only those parts of each animal that are components of its eating system. Have the class work together on the first animal, the elephant. Ask which parts are involved and have the class color each as it is mentioned. Have the children continue with the other pictures independently, and then review and compare the worksheets after completion. If a child has colored an unusual part, have him explain why he considers it to be part of the animal's eating system.

There may be some disagreement with respect to some part a child may say is part of the system. If he can establish some relation with eating, however remote, he is to be considered correct.

Worksheet 11
Unit 15
Name _____



Worksheet 12
Unit 15
Name _____

Worksheet 13
Unit 15
Name _____

Worksheet 14
Unit 15
Name _____

SECTION 6 A BULB-LIGHTING SYSTEM (Lesson 17)

PURPOSE

- To start with a set of objects and to use them in devising a system.
- To determine the conditions necessary to a bulb-lighting system.
- To develop an experimental method for classifying objects according to whether or not they can serve as connectors in a bulb-lighting system.

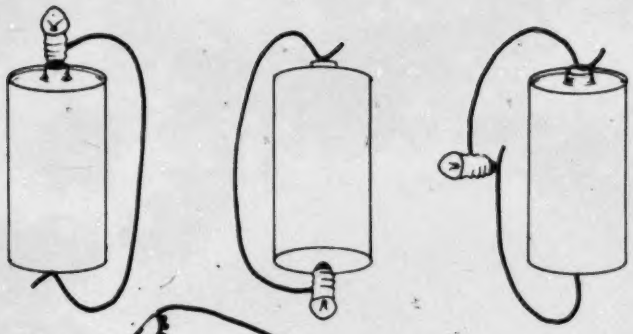
COMMENTARY

In most of the previous sections of this unit the children were presented with phenomena which they investigated to determine what the essential components of the systems were. In this section they are given an assortment of objects from which they are to choose a subset that can serve as the components of a system that they themselves devise. (The lesson is built around a bulb-lighting system, but the children are likely to devise other interesting systems as well.)

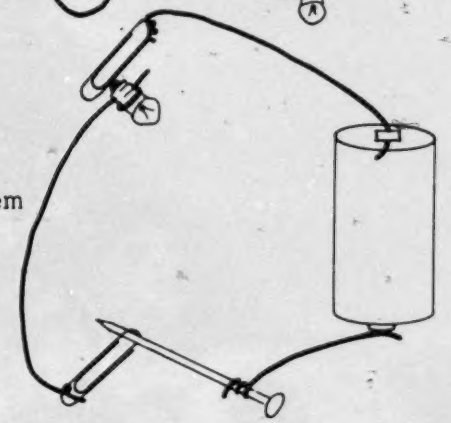
This section can help you evaluate the children's grasp of the basic ideas of the whole unit. Do the children describe their systems in terms of the interrelation of the parts and in terms of an analysis of the phenomena? In classifying their objects, do they specifically test each one to see if it will work as a connector in the bulb-lighting system?

In any circuit for lighting the bulb, the basic requirement is that there be some continuous metal connection between one end of the flashlight cell and the metal tip of the bulb, and between the other end of the cell and the threaded portion of the bulb. Of course, you will not point this out to the children. Let them discover as much as they can for themselves.

Three Simple Systems



A Complex System



If a few children discover that the clothesline will close the circuit successfully, make sure that they realize that there is a wire through the center, and that the wire has to make contact at both ends in order to close the circuit. Let them demonstrate this to the class.

Limit the discussion during this lesson to the systems and to what objects will or will not work in them. Do not get involved in any attempt to explain why or how the systems work. Even the most elementary explanation of electrical effects is too involved for early grades.

MATERIALS

-- for each group of four children --

a tray or box containing four of each of the following items:

- flashlight cell -- 1.5 volt
- flashlight bulb -- 2.25 volt (all four in a soufflé cup)
- rubber band
- #20 spikes

- masking tape, 6 in. strips placed on waxed paper
- string

short lengths (approximately 6 in.) of the following

- fine, bare copper wire
- soda straw
- fine plastic tubing
- insulated wire with insulation removed from 1/2 in. at each end
- plastic clothesline (wire-centered)
- paper strip, 1/2 in. wide
- magnetic tape
- ribbon

PROCEDURE

Activity A

Provide each group of four children with a tray or box of the materials listed above. Tell the children that each one is to choose a subset of three objects from the set of objects in his group's box. He is not to choose more than one of each kind of object for his subset; each subset should be made up of three different objects.

Have the children experiment with the objects they have chosen to see if they can discover a way to make something interesting happen. Allow adequate time for all to experiment. If children have problems in handling the various pieces of equipment, let two work together or suggest that some masking tape may be useful in making firm connections.

Ask the children to show some of the things they have discovered. One may have made a pendulum, another may have produced a sound by plucking a rubber band, etc. You should have allowed the experimentation period to continue until several children have devised systems in which a bulb is lit.

If no one in your class has found a way to light the bulb, direct them toward this problem as follows:

WHICH OBJECTS DO YOU THINK ARE NECESSARY FOR LIGHTING THE BULB? (Bulb, dry cell, wire.)

Children who did not select these three objects to work with should feel free to exchange those they did choose. If a child is having difficulty with the three objects, give a little more direction:

IF YOU TOUCH THE BULB TO ONE END OF THE CELL, HOW CAN YOU ALSO CONNECT IT TO THE OTHER END?

When all the children have devised a system in which their bulbs are lit, pose a new problem and give them time to work on it.

CAN YOU TAKE THE OBJECTS THAT ARE PART OF YOUR BULB-LIGHTING SYSTEM, ARRANGE THEM IN A DIFFERENT WAY, AND STILL GET THE BULB TO LIGHT?

Activity B

Have each group classify all the objects in the box into two subsets according to whether or not they can be used as part of a bulb-lighting system. The children should plan their own experimental methods for determining how to classify the objects. It is to be hoped that they will test each object in an orderly way. If a child notes that his classification can also be defined in terms of metal and non-metal, compliment him but do not attempt to guide the class to this interpretation.

Activity C

As another activity for small groups, have the children attempt to develop more complex arrangements of objects as bulb-lighting systems. (Some children may want to do this during their free time.) Such systems can be shown to the class, or if taped together, left on display. (Be sure that the systems on display are disconnected when not in use, to prevent the energy of the cells from being used up.)

Some child may discover that it is possible to design a system in which more than one bulb is lit. If several cells are included in one circuit it is possible that a bulb will be burned out, but otherwise there is no danger in any system which can be devised from the materials supplied.